San Francisco Bay Area Network
Phase II Vital Signs Monitoring Plan

Working Draft

[Golden Gate image here when posted to web site!]

San Francisco Bay Area Network (SFAN)
Eugene O'Neill National Historic Site (EUON)
Fort Point National Historic Site (FOPO)
Golden Gate National Recreation Area (GOGA)
John Muir National Historic Site (JOMU)
Muir Woods National Monument (MUWO)
Pinnacles National Monument (PINN)
Point Reyes National Seashore (PORE)
Presidio of San Francisco (PRES)

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Executive Summary

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Throughout the report, references are made to supporting sections, external documents, and web sites. For those references that appear as blue underlined text when the document is viewed in its electronic format, a hyperlink will connect the reader to the supporting information. Depress the "Ctrl" button and click the left mouse button simultaneously to follow the link. The web address is supplied for web-based documents.

Appendices exist in a separate file (SFAN_Phase II appendicesv9.doc). Primary appendices referenced in the SFAN Phase II report are listed numerically, in order of their appearance in the body of the report (e.g., Appendix 1, 2, 3, etc.) Secondary appendices (appendices within appendices) contained within workshop reports and other subdocuments are listed alphabetically, in the order they are referenced within the subdocument (e.g., Appendix A, B, C, etc.)

The report Glossary contains a list of monitoring terms and their definitions for the reader's benefit.

Chapter 1 Introduction and Background

1.1 Purpose

1.1.1 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources “unimpaired for the enjoyment of future generations (National Park Service Organic Act 1916).” National Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public to preserve and protect these resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park’s natural resources requires a multi-agency, ecosystem approach because most parks are open systems, with threats such as air and water pollution, and invasive species, originating from outside of the park’s boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes; the appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases may require a regional, national or international effort to understand and manage the resource. National parks are part of larger ecosystems and natural resources must be managed in that context. (See the report Glossary for a list of monitoring terms and their definitions.)

Natural resource monitoring provides site-specific information needed to understand and identify change in complex, variable, and imperfectly understood natural systems. Monitoring is defined as the "collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998)." Monitoring data help to define the normal limits of natural variation in park resources and provide a basis for understanding observed changes; monitoring results may also be used to determine what constitutes impairment and to identify the need for change in management practices. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

The intent of the National Park Service (NPS) monitoring program is to track a subset of park resources and processes, known as “Vital Signs,” that are identified as the most significant indicators of ecological condition for those specific resources and that are of the greatest concern to each park. This subset of resources and processes is part of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations,” including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on these resources. In situations where natural areas have been so highly altered that physical and biological processes no longer operate under natural conditions (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is not feasible, to ecologically sound management. The broad-based, scientifically sound information obtained through natural resource monitoring will have multiple applications for management decision-making, research, education, and promoting public understanding of park resources.

1.1.2 Legislation, Policy, and Guidance

National Park managers are directed by federal law and NPS policies and guidance to know the status and trends in the condition of natural resources under their stewardship to fulfill the NPS mission of conserving parks unimpaired (see Summary of Laws, Policies, and Guidance, http://science.nature.nps.gov/im/monitor/LawsPolicy.htm). The mission of the National Park Service is:

> "*...to promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified by such means and measures as conform to the fundamental purposes of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations* (National Park Service Organic Act 1916)."

As more natural and cultural resources were dedicated to National Park Service authority, Congress recognized that all parks are interrelated to preserve a single national heritage, require the same level of protection, and should operate under one set of guidelines. As a precursor to the concept of park networks, Congress affirmed:

> "*...that the national park system, which began with establishment of Yellowstone National Park in 1872, has since grown to include superlative natural, historic, and recreation areas in every major region of the United States...; that these areas, though distinct in character, are united through their inter-related purposes and resources into one national park system as cumulative expressions of a single national heritage; that, individually and collectively, these areas derive increased national dignity and recognition of their superb environmental quality through their inclusion jointly with each other in one national park system preserved and managed for the benefit and inspiration of all the people of the United States* **(**General Authorities Act 1970)."

Congress strengthened the NPS's protective function, and provided language important to recent decisions about resource impairment, when it amended the Organic Act in 1978 to state that "*the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established...*"

Recognizing the need to understand the condition of natural resources within the park system, a servicewide inventory and monitoring (I&M) program was established (NPS-75 1995; http://science.nature.nps.gov/im/monitor/nps75.pdf). The I&M program was given the responsibility to determine the nature and status of natural resources under NPS stewardship and to monitor changes in the condition of these resources over time. Information from inventory and monitoring efforts can then be incorporated into NPS planning, management, and decision making.

The Government Performance and Results Act (GPRA; 1993) was established to insure that daily actions and expenditures are guided by both long-term and short-term goals that are, in turn, consistent with Department of Interior agency missions. For the Park Service, four overarching goal categories guide the direction of more specific goals.

- Category I goals preserve and protect park resources.
- Category II goals provide for the public enjoyment and visitor experience of parks.
- Category III goals strengthen and preserve natural and cultural resources and enhance recreational opportunities managed by partners.
- Category IV goals ensure organizational effectiveness.

Specific, long-term goals must be quantifiable. As such, measurable outcomes provide the parks with tangible objectives and an effective means by which to measure progress toward their goals and objectives (See http://www.doi.gov/gpra/nps_sp_6.pdf for specific NPS long-term goals). A five-year strategic plan and an annual work plan outline the strategies for reaching these goals while an annual performance report evaluates the annual progress made toward GPRA goals.

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. The Act charges the Secretary of the Interior to "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*," and to "*...assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

The Natural Resource Challenge (1999; http://www.nature.nps.gov/challengedoc/) action plan refined the goals delineated in the NPS Strategic Plan designed to address GPRA goals. The action plan presented the challenges confronting the Park Service and strategic approaches for addressing these challenges over a five-year period. Extension of the Servicewide I&M program, the formation of collaborative park networks, and active recruitment and inclusion of scientists in complex park natural resource issues were among the strategies included in the action plan.

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill:

> *The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring*

program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data.

The 2001 NPS Management Policies updated previous policy and specifically directed the Service to inventory and monitor natural systems:

Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions.

Further, "*The Service will:*

- ♦ *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents.*
- ♦ *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources.*
- ♦ *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals.*
- ♦ *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames.*
- ♦ *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems* (2001 NPS Management Policies)."

Additional statutes provide legal direction for expending funds to determine the condition of natural resources in parks and specifically guide the natural resource management of network parks, including:

- ♦ Taylor Grazing Act 1934;
- ♦ Fish and Wildlife Act 1956;
- ♦ Fish and Wildlife Coordination Acts 1958 and 1980;
- ♦ Clean Air Act 1963, amended 1970 and 1990;
- ♦ Wilderness Act 1964;
- ♦ National Historic Preservation Act 1966;
- ♦ National Environmental Policy Act of 1969;
- ♦ Coastal Zone Management Act 1972;
- ♦ Clean Water Act 1972, amended 1977 and 1987;
- ♦ Marine Protection, Research and Sanctuaries Act 1972;
- ♦ Marine Mammal Protection Act of 1972, amended 1973, 1976-1978, 1980-1982, 1984, 1986, 1988, 1990, 1992-1994, and 1996;
- ♦ Endangered Species Act 1973, amended 1982;

- Migratory Bird Treaty Act 1974;
- Forest and Rangeland Renewable Resources Planning Acts of 1974 and 1976;
- Mining in the Parks Act 1976;
- Magnuson-Stevens Fishery Conservation and Management Act 1976, as amended 1978-1980, 1982-1984, 1986-1990, 1992-1994, and 1996;
- Executive Order 11990 (Protection of Wetlands) 1977;
- American Indian Religious Freedom Act 1978;
- Archaeological Resources Protection Act 1979;
- Federal Cave Resources Protection Act 1988.

1.2 Monitoring Goals and Strategies

1.2.1 Role of Inventory, Monitoring, and Research in Resource Management

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1.1; see also Definitions of Natural Resource Inventories, Monitoring, and Research, http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Definitions.doc). The NPS strategy to institutionalize inventory and monitoring throughout the agency consists of a framework (see Framework for National Park Service Inventory and Monitoring, http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Framework.doc) having three major components: (1) completion of 12 basic resource inventories upon which monitoring efforts can be based; (2) a network of 11 experimental or "prototype" long-term ecological monitoring (LTEM) programs begun in 1992 to evaluate alternative monitoring designs and strategies; and (3) implementation of operational monitoring of critical parameters (i.e., Vital Signs) in approximately 270 national parks with significant natural resources that have been grouped into 32 networks linked by geography and shared natural resource characteristics. (See the report Glossary for a list of monitoring terms and their definitions.)

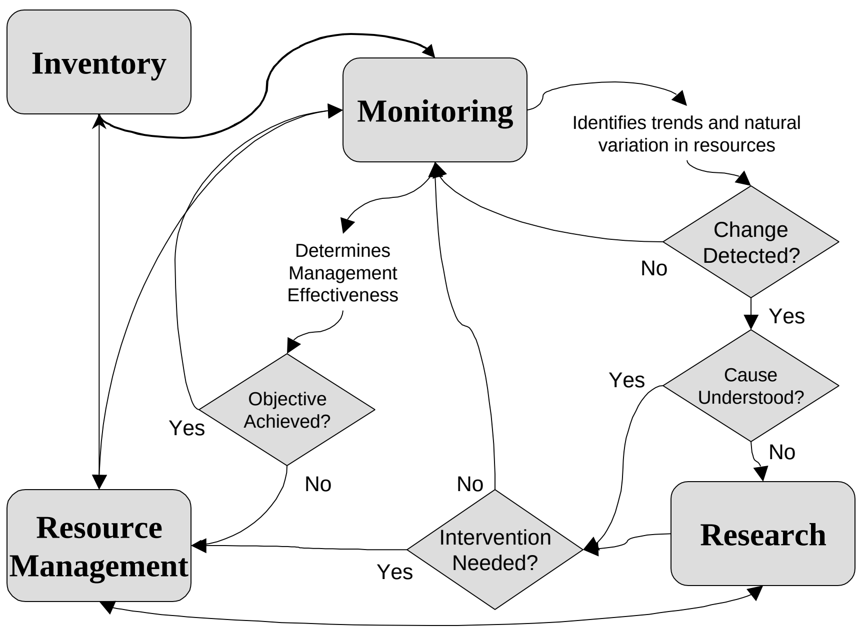


Figure 1.1. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modifed from Jenkins et al. 2002).

All parks with significant natural resources must possess at least a minimal complement of 12 resource inventory data sets to be able to effectively manage resources. The I&M program requires these parks to compile at least:

- A natural resource bibliography,
- Base cartographic data,
- A geology map,
- Soils map,
- Weather data,
- Air quality data,
- Location of air quality monitoring stations,
- Water body locations and classifications,
- Water quality data,
- Vegetation maps,
- A documented species list of vertebrates and vascular plants, and
- Species distributions for and status of vertebrates and vascular plants.

The network approach will facilitate collaboration, information sharing, and economies of scale in natural resource monitoring, and will provide parks with a minimum infrastructure for initiating natural resource monitoring that can be built upon in the future. Ten of the 32 networks include one or two prototype long-term ecological monitoring programs, which were established as experiments to learn how to design scientifically credible and cost-effective monitoring programs in ecological settings of major importance to a number of NPS units. Because of higher funding and staffing levels, as well as U.S. Geological Survey (USGS) involvement and funding in program design and protocol development, the prototypes serve as "centers of excellence" that are able to do more extensive and in-depth monitoring and continue research and development work to benefit other parks (see http://www1.nrintra.nps.gov/im/monitor/cupn/IM_Definitions.doc).

1.2.2 Goals for Vital Signs Monitoring

The servicewide goals for Vital Signs monitoring for the National Park Service are as follows:

- Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
- Provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management.
- Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
- Provide data to meet certain legal and Congressional mandates related to natural resource protection and visitor enjoyment.
- Provide a means of measuring progress towards performance goals.

1.2.3 Strategic Approaches to Monitoring

1.2.3.1 Scope and Process for Developing an Integrated Monitoring Program

During the development of the vision for park Vital Signs monitoring, it was clear that a "one size fits all" approach to monitoring design would not be effective in the NPS considering the tremendous variability in ecological conditions, sizes, and management capabilities among parks. Parks need considerable flexibility to develop an effective and cost-efficient monitoring program that addresses the most critical information needs of each park and that can be integrated with other park operations such as interpretation and maintenance activities. Additionally, this process needs to allow existing programs that have been carefully scrutinized, existing funding sources, and current staff to be combined with new funding and staffing available through the Natural Resource Challenge and the various divisions of the Natural Resource Program Center. Partnerships with federal and state agencies and adjacent landowners are necessary to effectively understand and manage resources and threats that extend beyond park boundaries, but these partnerships (and the appropriate ecological indicators and methodologies involved) differ for parks throughout the national park system. For example, parks in the Pacific Northwest need to select certain indicators and methodologies that are consistent with their National Forest Service neighbors and the Northwest Forest Plan, whereas parks in South Florida, in conjuction with the U.S. Army Corps of Engineers, South Florida Water Management District, and other partners, may select a completely different set of indicators and sampling protocols appropriate to restoration of the Everglades ecosystem.

The complicated task of developing a network monitoring program requires an initial investment in planning and design to guarantee that monitoring meets the most critical information needs of each park. The program must produce scientifically credible results that are clearly understood and accepted by scientists, policy makers, and the public, and that are readily accessible to managers and researchers. These front-end investments also ensure that monitoring will build upon existing information and understanding of park ecosystems and make maximum use of leveraging and partnerships with other agencies, organizations, and academia.

Each network of parks is required to design an integrated monitoring program that addresses the monitoring goals listed above and is tailored to the high-priority monitoring needs and partnership opportunities for the parks in that network. Although there will be considerable variability among networks in the final design, the basic approach to designing a monitoring program should follow five basic steps, which are further discussed in the Recommended Approach for Developing a Network Monitoring Program (http://science.nature.nps.gov/im/monitor/index.htm):

1. Define the purpose and scope of the monitoring program.
2. Compile and summarize existing data and understanding of park ecosystems.
3. Develop conceptual models of relevant ecosystem components.
4. Select indicators and specific monitoring objectives for each; and
5. Determine the appropriate sampling design and sampling protocols.

These steps are incorporated into a 3-phase, 5-year planning and design process that has been established for the monitoring program. Phase 1 of the process involves 1) defining goals and objectives; 2) identifying, evaluating and synthesizing existing data; 3) identifying preliminary monitoring questions; 4) developing draft conceptual models; and 5) completing other background work that must be done before the initial selection of ecological indicators (Figure 1.2). Each network is required to document these tasks in a Phase 1 report, which is then peer-reviewed and approved at the regional level before the network proceeds to the next phase. The Phase 1 report is a first draft of Chapters 1 and 2 of the final monitoring plan that present the Introduction/Background and Conceptual Models.

Phase 2 of the planning and design effort involves selecting and prioritizing Vital Signs and developing specific monitoring objectives for the parks in each network that will be included in the network's initial integrated monitoring program (Figure 1.2).

Phase 3 entails the detailed design work needed to implement monitoring, including the development of sampling protocols, a statistical sampling design, a plan for data management and analysis, and details on the type, content, and timeline of various products of the monitoring effort such as reports and websites.

The NPS Water Resources Division provides explicit guidance and funding for the water quality monitoring component of a network's monitoring program. Consequently, the NPS Water Resources Division requires networks to fully integrate the design and implementation of water quality monitoring with the network-based Vital Signs monitoring program. Networks have the option of producing a single, integrated monitoring plan that incorporates the "core Vital Signs" and water quality monitoring components using the 3-phase approach outlined above, or they can produce a separate document for the water quality monitoring component that follows the detailed guidance for water quality monitoring developed by the Water Resources Division (see http://www.nature.nps.gov/im/monitor/handbook.htm). The San Francisco Bay Area Network chose the former approach.

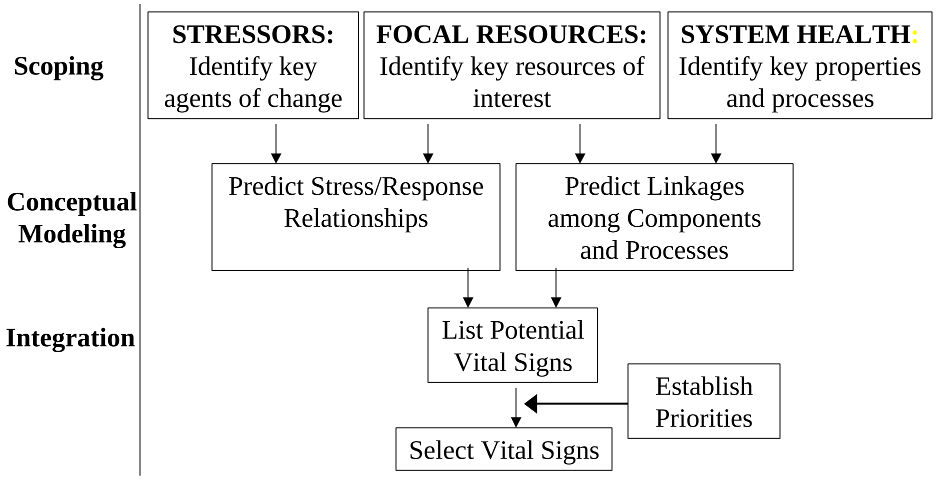


Figure 1.2. Basic approach to identifying and selecting Vital Signs for integrated monitoring of park resources (source: K. Jenkins, USGS Olympic Field Station).

1.2.3.2 Strategies for Determining What to Monitor

Monitoring is an on-going effort to better understand how to sustain or restore ecosystems, and serves as an "early warning system" to detect declines in ecosystem integrity and species viability before irreversible loss has occurred. As our understanding of ecological systems and the concepts of sustainability and integrity of natural systems has evolved, the classic view of the “balance of nature” has been replaced by a non-equilibrium paradigm which recognizes that ecological systems are regularly subject to natural disturbances such as droughts, floods, and fire that alter the composition and structure of the systems and the processes that shape them. Even in the absence of human activities, ecosystems are characterized by high variability in composition, structure and function. The goals of the Vital Signs monitoring program recognize the dynamic nature and condition of park ecosystems and the need to identify and separate “natural” variation from undesirable anthropogenic sources of change to park resources.

One of the key initial decisions in designing a monitoring program is deciding how much relative weight should be given to tracking changes in focal resources and stressors that address current management issues versus measures that are thought to be important to the long-term understanding of park ecosystems. An ecological indicator is most useful when it can provide information to support a management decision or to quantify the success of past decisions. The indicator must produce data that can be interpreted, clearly understood, and accepted by managers, scientists, policy makers, and the public. However, current understanding of ecological systems is constrained, and consequently, predictions of how park resources might respond to changes in various system drivers and stressors is limited. A monitoring program that focuses only on current threat/response relationships and current issues may not provide the long-term data and understanding needed to address high-priority issues that will arise in the future.

Should Vital Signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley (1993), Woodward et al. (1999), Jenkins et al. (2002) and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program, or alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring. Ultimately, the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches, while recognizing that the program will not succeed without also considering political issues. NPS, therefore, has adopted a multi-faceted approach for monitoring park resources, based on both integrated and threat-specific monitoring approaches and that builds upon concepts presented originally for the Canadian national parks (Figure 1.3; Woodley 1993).

Specifically, it is recommended that indicators be chosen from each of the following broad categories:

(1) **ecosystem drivers and processes** that fundamentally affect park ecosystems,
(2) **stressors and their ecological effects,**
(3) **focal resources** of parks, and
(4) **key properties and processes of ecosystem integrity**.

Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the National Park Service. See the report Glossary for a list of monitoring terms and their definitions.

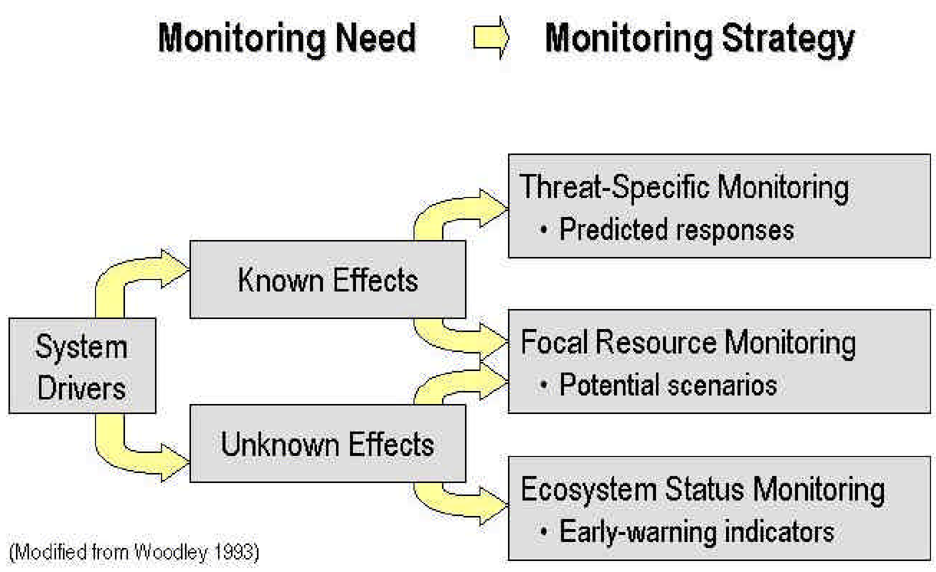


Figure 1.3. Conceptual approach for selecting monitoring indicators. In certain cases where good understanding exists between potential effects and responses by park resources (Known Effects), monitoring of system drivers, stressors, and effected park resources is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to improve long-term understanding and potential early warning of undesirable changes in park resources.

1.2.3.3 Integration: Ecological, Spatial, Temporal, and Programmatic

One of the most difficult aspects of designing a comprehensive monitoring program is integration of monitoring projects so that the interpretation of the whole monitoring program yields information more useful than that of individual parts. Integration involves ecological, spatial, temporal, and programmatic aspects. An ideal ecosystem monitoring strategy will employ a suite of individual measurements that collectively monitor the integrity of the entire ecosystem. One approach for effective ecological integration is to select indicators at various hierarchical levels of ecological organization (e.g., landscape, community, population, genetic; see Noss 1990). Similarly, spatial integration requires understanding of scalar ecological processes, coordinated location of comparably scaled monitoring indicators, and design of statistical sampling frameworks that permit the extrapolation and interpolation of scalar data. Temporal integration requires the development of a meaningful timeline for sampling different indicators while considering characteristics of temporal variation in these indicators. For example, sampling changes in the structure of a forest size class distribution may require much less frequent sampling than that required to detect changes in the composition or density of herbaceous groundcover. Programmatic integration requires coordinated monitoring planning and design by the Natural Resources Program Center (NRPC) divisions of Air Resources, Biological Resource Management, Geologic Resources, Natural Resource Information, and Water Resources to provide guidance, technical support and funding to the networks. Monitoring planning also needs to be coordinated and results communicated within and among parks and with other agencies and institutions. Coordinated monitoring planning, design, and implementation efforts encourage cooperative resource use, promote sharing of data among neighboring land management agencies, provide context for interpreting data, and encourage additional research. (See the report Glossary for a list of monitoring terms and their definitions.)

1.2.3.4 Limitations of the Monitoring Program

All monitoring programs have limitations that are a result of the inherent complexity and variability of park ecosystems, coupled with limited time, funding, and staffing available for monitoring. Ecosystems are loosely-defined assemblages that exhibit characteristic patterns on a range of scales of time, space, and organization complexity (De Leo and Levin 1997). Natural systems as well as human activities change over time, and it is extremely challenging to distinguish natural variability and desirable changes from undesirable anthropogenic sources of change to park resources. The monitoring program simply cannot address all resource management interests because of limitations of funding, staffing, and logistical constraints. Rather, the intent of Vital Signs monitoring is to monitor a select sub-set of ecosystem components and processes that reflect the condition of the park ecosystem and are relevant to management issues. Cause and effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause and effect relationship that can then be investigated with a research study. As monitoring proceeds, as data sets are interpreted, as our understanding of ecological processes is enhanced, and as trends are detected, future issues will emerge (Roman and Barrett 1999). The monitoring plan, therefore, should be viewed as a working document, subject to periodic review and adjustments over time as our understanding improves and new issues and technological advances arise.

1.2.3.5 SFAN Monitoring Plan and GPRA Goals

The SFAN Monitoring Plan is a significant and specific step towards fulfilling GPRA Goal Category I (Preserve Park Resources) for the network. The servicewide goal pertaining to Natural Resource Inventories specifically identifies the strategic objective of inventorying the resources of the parks as an initial step in protecting and preserving park resources (GPRA Goal Ib1). This goal tracks the basic natural resources information that is available to parks; performance is measured by what datasets are obtained. The servicewide long-term goal is to "acquire or develop 87% of the outstanding datasets identified in 1999 of basic natural resource inventories for all parks" based on the I&M Program's 12 basic datasets (Section 1.2.1). The SFAN Inventory Study Plan (2000) delineated what information exists for the network, its format and condition, and what information is missing. Based on the information acquired from the inventories, the parks will identify Vital Signs to monitor.

The Monitoring Plan will identify the monitoring indicators or "Vital Signs" of the network and develop a strategy for long-term monitoring to detect trends in resource condition (GPRA Goal Ib3). The 2002 Annual Performance Report identifies what steps have been accomplished to date and the number of personnel involved. The network goal is to identify Vital Signs for natural resource monitoring in a Monitoring Plan to be completed by September 30, 2005. GPRA goals specific to SFAN parks and relevant to the Monitoring Plan are listed in Table 1.1.

Table 1.1. GPRA goals for each park that pertain to information generated by the Inventory and Monitoring program of the San Francisco Bay Area Network.

GPRA Goal	Goal #	Parks with this goal
Resources maintained	Ia	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Disturbed lands restored	Ia01A Ia01B Ia1A Ib01A	PORE PORE GOGA, PRES JOMU
Exotic vegetation contained	Ia1B	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Natural resource inventories acquired or developed	Ib01	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Stable populations of federal T&E species or species of concern have improved status	Ia2B Ib02d	GOGA, MUWO, PORE
Unknown federal T&E species or species of concern populations have improved status	Ia2D	PORE
Improving federal T&E species or species of concern populations have improved status	Ia2A	PINN, PORE, GOGA, MUWO, PRES
Species of concern populations have improved status	Ia2X	GOGA, PRES, PORE
Vital signs for natural resource monitoring identified	Ib3	EUON, FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES
Water quality improvement	Ia04	FOPO, JOMU, GOGA, MUWO, PINN, PORE, PRES

1.2.3.6 San Francisco Bay Area Network Strategic Approach to Monitoring

The San Francisco Bay Area Network (SFAN) is one of eight networks formed in October 2000 in the Pacific West Region of the National Park Service. The SFAN is composed of eight park units: Eugene O'Neill National Historic Site (EUON), Fort Point National Historic Park (FOPO), Golden Gate National Recreation Area (GOGA), John Muir National Historic Site (JOMU), Muir Woods National Monument (MUWO), Pinnacles National Monument (PINN), Point Reyes National Seashore (PORE), and the Presidio of San Francisco (PRES). FOPO, GOGA, MUWO, and PRES are administered as one unit by GOGA. EUON and JOMU are managed jointly. PRES and EUON were not originally selected by WASO as part of the 270 parks nationwide with significant natural resources; however, the SFAN Steering Committee and Board of Directors decided that natural resource issues within these parks were sufficient to be included in the network. The SFAN was selected as one of the first three networks in the region to obtain monitoring funds because of need, capacity, and existing monitoring effort.

The SFAN has followed the basic process depicted in Figure 1.2 to select a subset of park resources and processes for monitoring. The schedule for completing the 3-phase planning and design process is shown inTable 1.2 (http://science.nature.nps.gov/im/monitor/schedule.htm).

Table 1.2. Timeline for the San Francisco Bay Area Network to complete the 3-phase planning and design process for developing a monitoring program.

Program Element	FY01 Oct-Mar	FY01 Apr-Sep	FY02 Oct-Mar	FY02 Apr-Sep	FY03 Oct-Mar	FY03 Apr-Sep	FY04 Oct-Mar	FY04 Apr-Sep	FY05 Oct-Mar	FY05 Apr-Sep	FY06 Oct-Mar
Data gathering, internal scoping											
Inventories to Support Monitoring											
Scoping Workshops											
Conceptual Modeling											
Indicator Prioritization and Selection											
Protocol Development, Monitoring Design											
Monitoring Plan Due Dates Phase 1, 2, 3					Draft Phase 1 Oct '02		Draft Phase 2 Oct '03		Draft Phase 3 Dec '04		Final Phase 3 Oct '05

The SFAN held three Vital Signs Monitoring Workshops between FY01 and FY02. PINN held a workshop in September 2001 (Appendix 1). EUON and JOMU jointly held workshops in January and August 2002 since both parks are in close proximity, have similar natural resources and issues, and are administered jointly (Appendix 2). Because of their previous collaborative efforts and the overlap in resources and management issues, PORE and the parks administered by GOGA jointly held a workshop in 1997 and held another workshop in July 2002 to revisit changes in national guidelines (Appendix 3). In each of these workshops, participants identified significant resources in the parks, identified key processes and stressors affecting the parks, potential monitoring questions, and recommended Vital Signs indicators that could address the monitoring questions. An initial prioritization of Vital Signs indicators and development of a conceptual model also were addressed. Participants included Park Service managers and staff, external natural resource managers, and scientists.

Subsequently, the SFAN Steering Committee integrated findings and recommendations from the separate workshops into a conceptual model for the network that includes significant natural resources, key processes and stressors, and monitoring questions with suggested indicators. The SFAN Vital Signs Workshop held March 19-20, 2003, was organized to review the SFAN integrated model and its related components and to identify network-wide Vital Signs indicators. To help expedite the prioritization process and to prepare for future sampling design and protocol development, participants also were asked to complete protocol questionnaires for each of the high priority indicators identified by their workshop group (Table 1.3). Essential information requested on the questionnaire included: indicator name, ecosystem type, metric, methods (including frequency, timing and scale), basic assumptions, constraints, and references. Indicator protocols used by individual parks were integrated with those obtained from the workshop and from information generated by a geology working group that met in October 2002. Additionally, vegetation and faunal working groups convened after the Vital Signs Workshop to refine the indicator protocol questionnaires by incorporating workshop comments and suggestions. All of this information was entered into a web-based, network database that was used to prioritize Vital Signs and to develop monitoring protocols for the individual parks and for the SFAN.

A detailed description of the scoping workshop is included in the San Francisco Bay Area Network Vital Signs Workshop Summary March 2003 (Appendix 4). A summary of preliminary scoping workshop reports, workshop materials, an agenda, and a participant list are included with the report. The Vital Signs selection and prioritization process used by the SFAN parks is introduced in the workshop report, but is covered in more detail herein (Chapter 3: Vital Signs).

Table 1.3. SFAN protocol questionnaire template with category definitions.

Protocol Questions – definitions

(**Note:** Please be sure to address items in **bold** as these denote areas of **essential** information.)

INDICATOR: Specific indicator

Type: Is the indicator a basic resource component/value, a stressor within the system, or in some cases, both.

Indicator Category: Is the link in the indicator matrix?

Ecosystem(s): Links the indicator to ecosystems within the parks.

Park(s): Identifies what park(s) the indicator is associated with.

Metric(s): Refers to the elements to be measured and the data to be collected.

Method: Provides a short description of a methodology or references a developed protocol. Please include reference to frequency, timing, and scale as described below.

- **Frequency:** Stipulates how often the indicator should be measured.
- **Timing:** Specifies the time of year that data collection should occur.
- **Scale:** Three scales will be identified: 1) indicates at what level the data will be collected in the nested spatial system, 2) on what scale the process or element operates and 3) at what scale can the analysis be inferred.

Monitoring Question(s): Provides justification as to the importance of measuring this indicator.

Basic Assumptions: Specifies the underlying assumption(s) that if not true, would possibly invalidate this indicator/methodology.

Research Need(s): Identifies any known research need(s) that would facilitate understanding of how this indicator fits within the ecosystem model.

Management Goal: Desired future condition.

Threshold/ Target Value: Stipulates the resource condition (numerically if possible) and the amount of variation from this condition that will be tolerated (accepted as natural variation).

Management Response: Specifies what management action is recommended if the threshold or target is not met.

Constraints: Lists issues/concerns about the indicator related to its successful implementation.

Status: Identifies whether monitoring is proposed, in development, or on-going.

References: Contacts, experts or literature relevant to the indicator.

1.3 Overview of Network Parks and Selected Natural Resources

1.3.1 Ecological Context: Park Resources and Issues

The following sections describe the range of environmental conditions and anthropogenic influences prevalent in the San Francisco Bay Area. The natural resources resulting from the interactions of these forces and existing raw materials also are considered. Descriptions of the individual parks and their associated natural resources are summarized in Appendix 5.

1.3.1.1 Setting and Boundary

The parks of the SFAN are within the central California coast range and share many ecosystems, ecosystem components, and associated threats. The elements that define the limits of a boundary include leadership (as within a community), authority (as dictated by legal action), and zone of influence. The legislative boundaries of the coastal parks of central California extend from Tomales Point, Marin County in the north, south to Milagra Ridge, San Mateo County, and reach their eastern and southern extremes inland in the Gabilan Mountains of San Benito County (Figure 1.4). The SFAN parks include nearly 200,000 acres of land, 1,300 mi^2 of surface waters (including streams, tributaries, lagoons, lakes, ponds, and reservoirs), and nearly 120 linear miles of shoreline.

The parks are bordered by three National Marine Sanctuaries (Gulf of the Farallones, Monterey Bay, and Cordell Bank), Bureau of Land Management (BLM) lands including the Clear Creek Management Area and the California Coastal National Monument, two National Wildlife Refuges, several state Areas of Special Biological Significance, and numerous state and regional parks such as Mt. Tamalpais State Park, Las Trampas Regional Wilderness Park (part of East Bay Regional Parks Distrcit), and Fremont Peak State Park. The California Coastal National Monument was designated by Presidential Proclamation in 2000, and includes all BLM administered islands, rocks, exposed reefs and pinnacles off the California coast above the high water mark (Table 1.4). GOGA and PORE are part of an International Biosphere Reserve and function as a part of a community of internationally significant reserves.

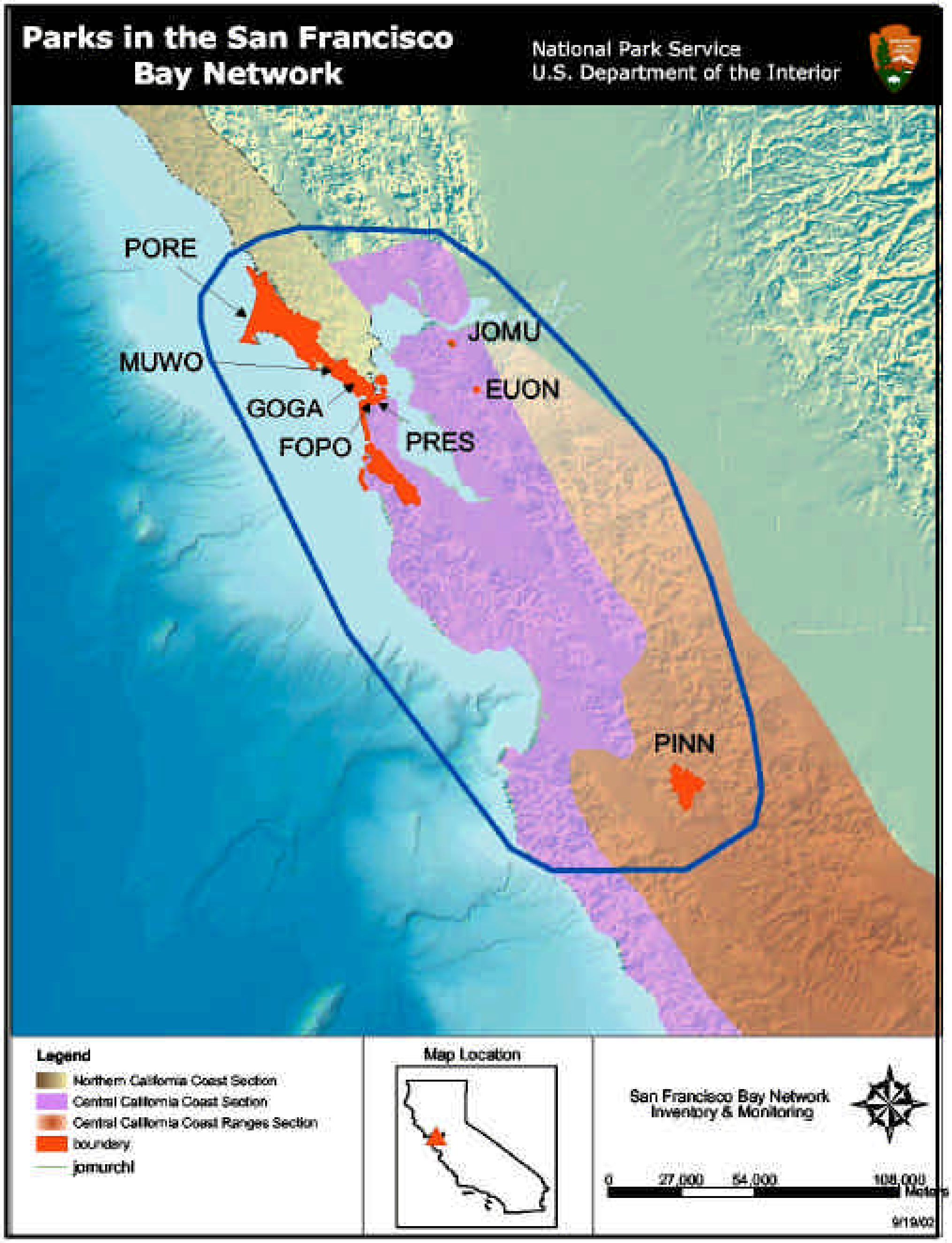


Figure 1.4. Location of the San Francisco Bay Area Network parks and the network's outer boundary line.

The Vital Signs monitoring plan designates two spatially nested network boundaries: a core and an outer limit. The core limit is composed of the NPS boundaries, including state parks, and adjacent watersheds. The outer limit is delineated by the broader boundary of the Golden Gate Biosphere Reserve, the three National Marine Sanctuaries, BLM lands, and the mouth and center of San Francisco Bay. The core limit takes into account the need to monitor upper and lower reaches of watersheds that extend beyond the legislative boundaries of the parks. The outer limits of the boundary take into account that marine species range widely in the region, and that shared monitoring activities with other partners is encouraged.

Table 1.4. Public or protected lands adjacent to SFAN park units.

Public or Protected Land	Agency*	Nearest NPS Unit
Angel Island State Park	State Parks	GOGA
Audubon Canyon Ranch and Cypress Grove Preserve	Audubon	GOGA, PORE
Bodega Bay Marine Reserve	CDFG	PORE
California Coastal National Monument	BLM	GOGA, PORE
Clear Creek Management Area	BLM	PINN
Golden Gate Biosphere Reserve	UNESCO	GOGA, PORE, JOMU
Cordell Bank National Marine Sanctuary	NOAA	PORE
Don Edwards National Wildlife Refuge	FWS	GOGA
Double Point Area of Special Biological Significance	SWQCB	PORE
Duxbury Reef State Reserve	State Parks	GOGA, PORE
Farallon Islands National Wildlife Refuge	FWS	GOGA, PORE
Fitzgerald Marine Reserve	San Mateo County Parks	GOGA
Fremont Peak State Park	State Parks	PINN
Estero Limantour Marine Reserve	CDFG	PORE
Gulf of the Farallones National Marine Sanctuary	NOAA	GOGA, PORE
Las Trampas Regional Wilderness	Regional Park	EUON
Los Padres National Forest	FS	PINN
Mount Diablo State Park	State Parks	JOMU
Monterey Bay National Marine Sanctuary	NOAA	GOGA
Point Reyes Marine Reserve	CDFG	PORE
Samuel P. Taylor State Park	State Parks	GOGA
San Juan Bautista SHP	State Parks	PINN
Tamalpais State Park	State Parks	GOGA
Tomales Point Area of Special Biological Significance	SWQCB	PORE
Tomales Bay State Park	State Parks	GOGA, PORE

*Audubon=National Audubon Society; BLM=U.S. Bureau of Land Management; CDFG=California Department of Fish and Game; FS=USDA Forest Service; FWS=U.S. Fish and Wildlife Service; NOAA=U.S. National Oceanographic and Atmospheric Administration; Regional Park=East Bay Regional Parks; State Parks=California State Parks; SWQCB=California State Water Quality Control Board; UNESCO=United Nations Educational, Scientific and Cultural Organization.

1.3.1.2 Climate

Climate in the SFAN is characterized by hot, dry summers and rainy, mild winters typical of a moderate Mediterranean climate. Temperatures average 50 to 65°F in the Coast Range, but in the inland valleys and at Pinnacles temperatures can exceed 90°F regularly in the summer. Precipitation, which ranges from 15 to 40 inches per year, extends from fall through spring, and increases with elevation. Precipitation typically occurs as rainfall. Snowfall is rare in the region. Frost and short periods of freezing weather occur occasionally in winter and mostly in inland valleys. The growing season lasts 120 to 270 days (National Weather Service 2003).

Coastal areas have a more moderate climate than the interior and can receive significant moisture from fog in summer. Consequently, inland areas receive about half the rainfall as areas along the coastal range. With this variability, many microclimates occur. For example, Point Reyes Headland in the summer can be 55°F with fog and wind in contrast to Olema Valley, just 15 miles distance, with temperatures above 80°F and no wind (National Weather Service 2003).

1.3.1.3 Geology

Geologic history has shaped the topography of the region creating large bays, coastal ridges paralleling the coastline, and unusual features. Coastal ridges that parallel the coast vary in elevation between 500 to 3,500 feet. They include the Inverness and Bolinas Ridges in the north, Diablo Mountains inland of San Francisco Bay, and the Gabilan Mountains to the south. Special features include the Pinnacles rock formations and Point Reyes Headland. The area, located in the Coast Ranges geomorphic province, consists of parallel ranges, and folded, faulted, and metamorphosed strata; the rounded crests are of sub-equal height.

In geologic time, central California has been exposed to extraordinary forces that have shaped the region. The ancestral San Andreas Fault links all of the park units. The fault starts at Pinnacles as a block in the middle of Miocene volcanics (formed 23 million years BP and consisting of a fairly soft, vertical component of tectonics) and extends northward to Point Reyes where the fault ruptures the surface and forms Bolinas Lagoon and Tomales Bay. Movement of the Pacific plate northward along the San Andreas faultline continues today. Combined with the massive glaciations of the Pleistocene and climatic conditions, these forces have created the distinctive topography of the region. Coastal ranges are no older than the Pleistocene, but in the Pliocene, a long embayment connected Pinnacles from the southern Gabilan Range with northern Point Reyes along both sides of the San Andreas Fault. San Francisco Bay itself was formed as a late Pliocene structural depression that was flooded several times due to Pleistocene glacial cycles. The Mendocino Coast Range extends north from San Francisco Bay to Humboldt Bay and is composed of Franciscan block similar to southern coastal ranges. Point Reyes Headland is a distinct geomorphic feature of this coastline that is granitic rock on the west side of the San Andreas faultline capped with Paleocene sedimentary rocks. Throughout the area are well developed Pliocene marine sedimentary rocks. Pinnacles is a geologic area of special interest due to the distinctive topography with spires, caves and jumbled rocks as a result of a downfaulted block and erosion of rhyolite breccia volcanic rocks (Norris and Webb 1990).

1.3.1.4 Water Resources

1.3.1.4.1 Overview of Aquatic Resources

The SFAN has many unique aquatic resources that are significant in an ecological and economic context. Aquatic resources in the SFAN include streams, bays, estuaries, lagoons, lakes, reservoirs, freshwater and estuarine marshes, and seeps. The combination of marine and freshwater aquatic systems within the network supports a variety of threatened and endangered species including the California freshwater shrimp (*Syncharis pacifica*), coho salmon (*Oncorhynchus kisutch*), steelhead trout (*Oncorhynchus mykiss*), the California red-legged frog (*Rana aurora draytonii*), tidewater goby (*Eucyclogobius newberryi*), Tomales roach (*Lavinina symmetricus ssp 2*), and Northwest pond turtle (*Clemmys marmorata* ssp. *mormorata*). Commercial operations include a significant herring fishery in Tomales Bay, oyster growing in Tomales Bay and Drakes Estero, and beef and dairy cattle ranching in PORE and GOGA.

Several NPS efforts to improve the condition of water resources within SFAN are underway. The Redwood Creek watershed and MUWO are currently the focus of a variety of activities including watershed planning, transportation planning, water quality and water rights investigations, sensitive species monitoring, aquatic system and riparian restoration, invasive non-native plant removal and habitat restoration, and GIS mapping of all watershed features. Similar activities are occurring throughout the network. Several stream restoration projects are on-going at PORE including bank stabilization and dam removal projects. Restoration efforts for Chalone Creek (PINN) and its floodplain have also been initiated. Streambank restoration (including removal of invasive species, erosion control, and bank stabilization) is also proposed along Alhambra Creek and its tributaries (JOMU), and a feasibility study for a wetland restoration is being conducted at EUON. Tidal wetland restoration efforts are on-going at PORE, GOGA, and PRES. Wetlands inventories are being conducted at GOGA (partially funded by the I&M program) as well as PORE (funding through NPS-WRD). GOGA also is implementing the removal of a small earthen dam in the Tennessee Valley portion of the Marin Headlands to control bullfrogs that are breeding in the pond behind the dam. The project also will restore a more natural flow to the creek, allowing the creek to return to its natural channel and prevent erosion on the banks downstream of the dam. In addition, the Tennessee Hollow Watershed Project will “daylight” (run above ground again) several sections of the creek that have been buried underground in conveyances. The project will restore the riparian corridor from headwaters to its confluencw with Chrissy Marsh. These restoration efforts have focused on the protection and restoration of habitat known to benefit T&E aquatic species as well as water quality. Many of the ecological and physical monitoring efforts assist in identifying pertinent management and scientific issues for the Vital Signs Monitoring program.

Many of the watersheds within SFAN parks receive substantial attention from the surrounding communities. A variety of stake-holder based watershed groups have been established in the last 10 years to address problems related to water quality and watershed health. Examples of these organizations include the Tomales Bay Watershed Council (TBWC), the Tomales Bay Shellfish Technical Advisory Committee (TBSTAC), the Tomales Bay Agricultural Group (TBAG), the Bolinas Lagoon Technical Advisory Committee (BLTAC), the Friends of Alhambra Creek (including Franklin Creek), and other groups. NPS staff are involved to varying degrees with these community groups, often providing technical expertise in a variety of resource management fields.

1.3.1.4.2 Watershed Characteristics and Water Quantity

The hydrologic systems are very flashy, with high runoff in the wet winter, and very low to intermittent flow dominating summer conditions. In response to these hydrologic conditions and the highly active geologic processes associated with the San Andreas Fault, stream channels are typically dynamic. Chalone Creek in PINN includes a highly dynamic and mobile sand bed that typically dries in the summer months. Watersheds within JOMU and the developed portions of GOGA are highly altered by development and urbanization. These systems are normally highly confined, with natural processes engineered out of the stream system. Within the Marin and San Mateo County portions of GOGA, as well as PORE, watersheds remain fairly stable and functional, supporting threatened coho salmon and steelhead trout. Stream systems in these areas have been impacted by historic or current agricultural activities as well as more dispersed development.

Watersheds are relatively small ranging from the approximately 5 mi^2 Franklin Creek watershed (JOMU) and 9 mi^2 Redwood Creek watershed (GOGA/MUWO) to the approximately 88 mi^2 Lagunitas Creek watershed (PORE/GOGA). The drainage area of Chalone Creek (PINN) just downstream of the park is roughly 70 mi^2. Other significant watersheds within the SFAN include Pine Gulch Creek (PORE; 6.5 mi^2) and Olema Creek (PORE; 14.5 mi^2) which are included in both PORE and GOGA lands. There are 130 linear miles of streams within the legislative boundaries of the SFAN.

Land use within the SFAN watersheds vary from coastal watersheds in wilderness areas to an urbanized watershed managed as a public water supply. Lobos Creek in the Presidio of San Francisco (PRES) is the only free-flowing (above ground) creek in the city. Land uses within the more rural watersheds include agricultural and commercial (e.g., beef and dairy cattle ranching, viniculture, oyster harvesting, and equestrian operations) as well as predominantly wilderness areas.

Stream discharge in network streams has been monitored by NPS for several years. The largest watershed in the SFAN, Lagunitas Creek, has been monitored by the USGS since 1974. The extremes for Lagunitas Creek for the period of record range from 22,100 cubic feet per second (cfs) in the floods of January 1982, to 0.01 cfs during the drought of 1977. Flows in Redwood Creek, Olema Creek, and Pine Gulch Creek range from intermittent to 3,000-4,000 cfs. The portion of Chalone Creek within PINN is ephemeral to intermittent in the summer. In winter, the highest recorded discharge of 2,850 cfs was recorded in 1998, an El Niño-Southern Oscillation year.

Municipal water withdrawals occur on Redwood Creek and Lagunitas Creek. The State Water Board has a mandated release (from reservoirs) of 8 cfs for Lagunitas Creek in normal years and 6 cfs during drought years. A cooperative planning process to allocate water use and operations for commercial organic agricultural withdrawals is on-going for Pine Gulch Creek. Within Redwood Creek and Easkoot Creek (GOGA), NPS monitoring has shown a direct impact between water withdrawals and salmonid habitat. Through this monitoring, the NPS has led the initiative to protect instream flow impacted by municipal water withdrawals. Water withdrawal on Olema Creek is not a major concern but withdrawals on Franklin Creek have not yet been assessed. Groundwater wells exist along Chalone Creek.

The SFAN is located within two subregions of USGS Water Resource Region 18. These include Subregion 1805 – San Francisco Bay and Subregion 1806-Central California Coastal. PORE, GOGA, PRES, MUWO, FOPO, JOMU, and EUON fall within subregion 1805 while

PINN falls within Subregion 1806. JOMU is within the 644 mi^2 Suisan Bay hydrologic unit code (HUC). Parts of GOGA and EUON are within the 1200 mi^2 San Francisco Bay HUC. PORE and portions of GOGA are within the 339 mi^2 Tomales-Drakes Bay HUC. Portions of GOGA are within the San Francisco Coastal South HUC (256 mi^2).

1.3.1.4.3 Water Quality Criteria

All of the park units except PINN are regulated by the San Francisco Bay Regional Water Quality Control Board (RWQCB, part of the State Water Resources Control Board). PINN is within the Central California Coast RWQCB. Management criteria for water bodies within the state of California are established by these Regional Boards. Through their Basin Plans the Regional Boards have set numerical and narrative objectives for surface waters (Tables 1.5 and 1.6). Several parameters (e.g., nitrates, phosphates) that are considered of importance to existing SFAN park water quality monitoring programs do not have criteria established by the Regional Board. Basin Plans outline the beneficial uses assigned to each stream that is a significant surface water feature. The specific water quality criteria to be met will depend on the beneficial uses of each water body. The combined beneficial uses of the streams within the network are listed in (Table 1.7). A separate document, the Ocean Plan, was produced by the State Board to regulate ocean waters.

Table 1.5. Objectives for physical parameters in surface waters in the San Francisco Bay Area.

Parameter	Water Quality Objective
Dissolved Oxygen tidal waters	Downstream of Carquinez bridge 5.0 mg/L minimum Upstream of Carquinez bridge 7.0 mg/L minimum
Dissolved Oxygen non-tidal waters	Cold water habitat 7.0 mg/L minimum Warm water habitat 5.0 mg/L minimum
pH	Less than 8.5 and greater than 6.5
Un-ionized ammonia	Annual Median 0.025 mg/L as N Maximum Central Bay 0.16 mg/L as N Maximum Lower Bay 0.4 mg/L as N

Table 1.6. Objectives for biological parameters in surface waters in the San Francisco Bay Area.

Beneficial Use	Fecal Coliform (MPN/100mL)	Total Coliform (MPN/100mL)
Contact recreation	Log mean < 200 90^{th} percentile < 400	Median < 240 No sample > 10,000
Non-contact recreation	Mean < 2000 90^{th} percentile < 4000	
Shellfish harvesting	Median < 14 90^{th} percentile < 43	Median < 70 90^{th} percentile < 230

Table 1.7. Beneficial uses of streams within the SFAN.

Parameter	Water Quality Objective
AGR	Agricultural Supply
COLD	Cold Freshwater Habitat
COMM	Commercial and Sport fishing
EST	Estuarine Habitat
FRSH	Freshwater Replenishment
GWR	Groundwater recharge
IND	Industrial Service Supply
MAR	Marine Habitat
MIGR	Fish Migration
MUN	Municipal Supply
NAV	Navigation
RARE	Preservation of Rare and Endangered Species
REC 1	Contact Water Recreation
REC2	Non-contact Water Recreation
SHELL	Shellfish Harvesting
SPWN	Fish Spawning
WARM	Warm freshwater habitat
WILD	Wildlife Habitat

1.3.1.4.4 Significant Waters

The State Water Resources Control Board (part of the California Environmental Protection Agency) has established four Areas of Special Biological Significance (ASBS) within the legislative boundaries of the SFAN parks. These include the Point Reyes Headlands, Bird Rock, Double Point, and the James Fitzgerald Marine Preserve. The Point Reyes Headlands, Bird Rock, and Double Point are managed by PORE. Duxbury Reef (adjacent to the PORE legislative boundary) is also an ASBS. These areas were chosen through a nomination process based primarily on habitat quality and are limited to coastal areas; inland areas have not yet been assessed. The procedure for this nomination process is in the California Ocean Plan (2001) developed by the State Water Resources Control Board. No other “significant waters” (e.g., Outstanding Natural Resource Waters, or ONRW) exist in the SFAN or its extended watersheds.

1.3.1.4.5 Impaired Waters

In 2000, the San Francisco Bay RWQCB identified both Lagunitas Creek and Tomales Bay (PORE/GOGA) as impaired by fecal coliform, sediment, and nutrients (Table 1.8). In the same year, Marin County announced a fish consumption advisory for Tomales Bay due to mercury bioaccumulation associated with an abandoned mercury mine in the Walker Creek watershed. The RWQCB has established a timeline for development of Total Mean Daily Loads (TMDLs) associated with these impairment listings. Required monitoring (by NPS and others) for the TMDL program will include monthly monitoring plus five consecutive weeks of monitoring in the winter.

Table 1.8. Impairment listings within the SFAN.

Water body	Park Unit	Pollutant (s)	TMDL Timeline from RWQCB		
			TMDL Report	TMDL with Implementation Plan	Basin Plan Amendment
Tomales Bay	PORE/GOGA	Pathogens	2002	2003	2004
Tomales Bay	PORE/GOGA	Mercury	2003	2004	2005
San Francisquito Creek	GOGA	Sediment	2004	2005	2006
Tomales Bay	PORE/GOGA	Sediment Nutrients	2005	2006	2007
Lagunitas Creek	PORE/GOGA	Pathogens, Sediment, Nutrients	2005	2006	2007

1.3.1.5 Biome

Biomes are large geographical areas characterized by major ecological communities of plants and animals that display distinctive adaptations to that particular environment (Botkin and Keller 1995). Climate and geology are the dominant environmental variables influencing organisms in a given area and are, therefore, the key determinants of biome types in a region (see 1.3.1.6 Biogeography). Biomes are classified according to their predominant vegetation, but associated seral communities and persistent, sub-dominant communities also are considered in most classification schemes. Biomes are dynamic and have changed over geologic time as climate and geology have changed. Anthropogenic changes, however, have affected broad-scale ecological processes and community composition in the short term. Biomes have been affected by these changes.

The Mediterranean Division of eco-regions of California is situated on the Pacific coast between latitudes 30° and 45° N and is distinguished by alternate wet and dry seasons (Bailey 1995). Both the SFAN and the Mediterranean Network are within this division. The area is distinguished as a transition zone between the dry west coastal desert and the wet west coast. Mediterranean-type ecosystems host a disproportionate share of plant species worldwide in both the number of species and the number of rare or locally endemic species (Dallman 1998). The major biomes of the parks include forests, grasslands, savannahs, and several types of aquatic environments.

The vegetation is typically dominated by hard leaved evergreen trees and shrubs called sclerophyll forests that can withstand severe drought and evaporation in the summer (Bailey 1995). The pattern of plant community distribution consistently has forest on north facing slopes and on wetter sites, chaparral/scrub on south facing slopes and drier sites, and riparian corridors between ridges and along valleys. Additionally, the plant communities vary with distance from the marine influence, temperature, and elevation.

The SFAN parks span this Mediterranean transition zone and fall within three provinces: the California Coastal Chaparral Forest and Shrub, the California Dry Steppe, and the California Coastal Steppe, Mixed Forest and Redwood Forest (Bailey 1995).

California Coastal Chaparral Forest and Shrub Province: The landform of this province is discontinuous coastal plains, low mountains and interior valleys adjacent to the ocean from San

Francisco Bay south. JOMU and EUON and parts of GOGA and PINN reside within these provinces. Vegetation includes forests dominated by endemic Monterey cypress (non-native), Monterey pine (non-native), and Bishop pine. In lower elevations, sclerophyll forests consist of live oak and white oak. Chaparral forms a dwarf forest in some areas and consists of chamise and various manzanitas. Coastal areas are dominated by coyote bush, sagebrush and lupine.

California Dry Steppe Province: PINN is the only park of the network that resides within this province. This section is in both the Transverse Range and Peninsular Range geomorphic provinces (Bailey 1995). The area has narrow ranges and broad fault blocks, alluviated lowlands, and dissected westward sloping granitic uplands. Summers in this area are very hot in temperature and water scarcity resulting in dry stream beds occurs in many areas. Many streams that flow eastward in alluvial or weak bedrock channels to the Great Valley Section do not flow throughout the summer. The dominant vegetation types include savannahs with interior live oak, valley oaks and blue oaks, grasslands with introduced annual grasses, and shrublands with chamise.

California Coastal Steppe, Mixed Forest and Redwood Forest Province: The Coast Ranges are gently to steeply sloping low mountains or marine terraces underlain by shale, sandstone, and igneous and volcanic rocks. These areas are confined to the coast and extend no farther inland than 35 miles with elevations below 3,000 feet. JOMU, GOGA, MUWO, FOPO, PRES and PORE and EUON reside partly or entirely within this province. The climate is dominated by the influence of a cool marine air layer producing milder temperatures in the summer. Heavy fogs commonly occur along the coast in the summer; the average number of fog days is higher than anywhere else in the United States (Bailey 1995). Forest stands of this biome are dominated by Redwoods and Douglas fir with understory vegetation including California huckleberry, ferns and salal. Inland are found mixed hardwood conifer forests including tanoak, coast live oak, California laurel, Pacific madrone, and chinquapin. Coastal headlands, where intense winds occur, tend to be barren, dune covered or covered with grasslands.

In addition to Bailey's (1995) ecoregions, the agencies of California developed a guide that identifies the dominant habitat types and their associated wildlife species (Mayer and Laudenslayer 1988). SFAN vegetation communities include more than half of the habitat types described in the California guide (Table 1.9).

Table 1.9. California wildlife habitats in the SFAN parks (Mayer and Laudenslayer 1988).

Habitat Description	Parks
Tree dominated	
Douglas Fir	GOGA, MUWO, PORE
Redwood	GOGA, MUWO, PORE
Coastal Oak Woodland	GOGA, MUWO, PORE
Blue Oak Woodland	JOMU, PINN
Eucalyptus	GOGA, PORE
Valley Foothill Riparian	All
Valley Oak Woodland	PINN
Shrub dominated habitats	
Mixed Chaparral	GOGA, JOMU, PINN, PORE
Chamise Redshank	PINN
Coastal Scrub	GOGA, PORE
Herbaceous dominated habitats	
Annual Grassland	All
Perennial Grassland	All except PINN
Wet Meadow	GOGA, PINN, PORE
Fresh Emergent Wetland	GOGA, JOMU, MUWO, PORE
Saline Emergent Wetland	GOGA, PORE, PRES
Pasture	GOGA, PORE
Aquatic Habitats	
Riverine	GOGA, JOMU, MUWO, PINN, PORE
Lacustrine	GOGA, PINN, PORE
Estuarine	GOGA, PORE, PRES
Marine	FOPO, GOGA, PORE, PRES

Marine Communities: Just as the terrestrial biomes are dominated by climate and geology, so too are the marine biotic communities of central California. The marine zones are generally divided into pelagic, subtidal, and intertidal zones based on water masses, distance from shore, bathymetry, and tidal exposure. The biota of these zones have distinctive communities. For example, in the pelagic zone, phytoplankton that bloom in summer and fall are the dominant vegetation type. In the subtidal zone, though, various species of kelp are dominant, and in the intertidal zone numerous algae adapted to daily desiccation are dominant. The simple classification by zonation, though, belies the complexity and dynamic nature of these ecosystems. Some habitats such as upwelling areas around islands and headlands are semi-permanent. However, nearshore currents driven by winds and tides form micro-habitats in the water column with jets, squirts and eddies where organisms such as zooplankton are entrained. Predators are then attracted to these semi-permanent and ephemeral features.

Convergence of oceanic currents rising from the abyssal plain over a steep submarine cliff also makes the marine and coastal shoreline habitats complex and diverse. The California coast is only one of five areas of eastern boundary coastal upwelling, oceanic currents worldwide and the only one in North America (Thurman 1988). In addition, a plume of warmer, freshwater exiting the San Francisco Bay extends out into the Gulf of the Farallones. These nutrient rich waters support abundant and diverse fauna. This upwelling-driven productivity cycle is vulnerable, though, to changes in sea temperature along the equator resulting in changes in wind persistence and intensity (i.e., the Pacific Decadal Oscillation, the El Niño-Southern Oscillation, or La Niña events).

More than one-third of the world's cetacean species occur in these waters. Significant haul-out areas for five species of pinnipeds are used year round and represent one of only eleven mainland breeding areas for northern elephant seals in the world and 20% of the mainland breeding population of harbor seals in California. Eleven species of seabirds breed within the parks and over 80 waterbird and shorebirds species were identified in the parks during the 1997-99 inventories (Kelly and Etienne 1999). Recognizing the extraordinary significance and exposure to threats in the region, the UNESCO Man in the Biosphere program designated the Central California International Biosphere Reserve in 1988, encompassing six of the eight parks, including adjacent coastal waters.

1.3.1.6 Biogeography

Although climate, broad-scale geologic features, and intermittent disturbance cycles have defined the framework for spatial patterns of species biodiversity in the SFAN, the interplay of three fundamental processes—evolution, extinction, and dispersal—has shaped the distribution and diversity of species that presently inhabit the Central California region. For example, the significant amount of endemism and rarity is the result, in part, of the complex and disjunct geology (Dallman 1998). Small populations of rare plant and associated animal species coevolved in unique habitats such as coastal bluffs and serpentine soils. Migration across the Bering Straits of terrestrial vertebrates, including humans, populated the region in waves. In response to climatic changes or other factors, species established and flourished, or they were extirpated. Although many extinct or extirpated species faced their demise because of human actions, glaciation, sea level rise, and isolation played a part.

Marine species that occur along the coastal margins and on the continental shelf have evolved and dispersed with changing sea levels, sea temperatures, geostrophic currents, and coastal processes over several millennia. Movement of tectonic plates along the Pacific continent contributed to the erosion, deposition, and eustatic sea level changes, further influencing the evolution and distribution of species. In central California, the range of marine species associated with the Californian and Oregonian Provinces overlaps, resulting in even greater species diversity. The range of species has shifted north and south depending on changes in sea temperature associated with warming (e.g., the Pacific Decadal Oscillation and El Niño-

Southern Oscillation) and cooling trends (e.g., La Niña events) that affect productivity (Francis and Hare 1994).

1.3.1.7 Human History

The earliest known archaeological materials unearthed in the San Francisco Bay Area date back approximately 5000 – 5500 years (Olmsted 1986). The people who left these artifacts, the Ohlone, practiced diverse and highly developed subsistence activities that included digging wells, damming waterways, propogating desirable plant species by sowing wild seeds, tending native root crops and wild grapes, and by irrigating, harvesting wild plants, grain storage, regulated hunting and fishing, and using fire to selectively manage food sources and wildlife habitat (Moratto 1984). Over 10,000 Ohlone people established extensive trade networks throughout the region exchanging food, obsidian, clothes, shells, and other materials by the time Europeans arrived in the Bay Area (Mayer 1974). Evidence from a fire history study conducted at PORE suggests that fires occurred on 7-13 year cycles throughout Ohlone occupation (Brown et al. 1999). After the arrival of Europeans, fire suppression became the dominant land management practice altering the availability of plant materials and game populations.

Spanish settlement in 1776 led to the establishment of the Presidio and the Mission of San Francisco de Asis in the area (Mayer 1974). Spanish soldiers and missionaries exposed the Ohlone people to the ways of European culture, leading to the inevitable deterioration of Ohlone culture and the loss of its people to introduced diseases.

As control of the area transferred to Mexican governance, ranching became the dominant way of life (Mayer 1974). Ranchers grazed cattle that were used for beef and hides, and developed with merchants steady trade relations that led to ever increasing numbers of non-Mexicans in the region (Olmsted 1986). Grazing continues to be an important element of the landscape in parts of Marin, San Mateo, and San Benito Counties today.

Russians settled in Fort Ross in the early 1800s but explored, traded, trapped, and collected plant specimens throughout this region. They also hunted marine mammals and collected eggs from seabirds on the Farallon Islands and may have hunted and gathered at PORE (History of the Russian Settlement 2003).

The discovery of gold in 1848 transformed San Francisco from a small town to a booming city and seaport as travelers passed through San Francisco from China, New Zealand, Australia, Mexico, Europe, and the United States seeking fortune (Olmsted 1986). As a result, San Francisco's population grew from 459 people to approximately 30,000 people between 1847 and 1849 (Olmsted 1986). The growing population intensified the need for agriculture, ranching, imports, and other goods and services required to sustain itself. Simultaneously, improved mining operations such as mine excavation and hydraulic mining techniques led to pollution of drinking water, siltation of water bodies, and more frequent flooding.

In April 1906, a massive earthquake and the three days of fires that followed destroyed 28,000 buildings, 2800 acres, and claimed 3000 lives (Olmsted 1986). The epicenter of this earthquake corresponds with the PORE park headquarters in Olema Valley. Earthquakes, fires, floods, and mudslides continue to plague the Bay Area to this day.

Despite the 1906 disaster, development and population growth continued throughout the Twentieth Century in the Bay Area. Dams were built to provide water and power to the area. The Golden Gate Bridge and the San Francisco-Oakland Bay Bridge were built in the 1930s to expedite travel but increased traffic and created a need for more parking facilities. Shipyards expanded during World War II creating job opportunities. Concomittant with its growth, the San Francisco Bay Area has served as a magnet for America's counterculture, refugees of Latin America's civil wars, and more recently, internet entrepreneurs and technocrats from every corner of the globe (KRON-TV 1999).

The resulting demographic, technological, and cultural change has created one of the most densely populated areas in the United States. Over seven million people reside in the nine Bay Area counties encompassing 7336 mi^2 with most of the population concentrated in the three largest cities in the area (San Francisco, San Jose, and Oakland) (US Census Bureau 1999).

With the growth that has become characteristic of the San Francisco Bay Area has come development and the demands on the environment associated with increasing population, affluence, and technology. Both past and present growth and management pressures are evident in the SFAN parks.

1.3.1.8 Natural Disturbance

Both abiotic and biotic processes comprise the natural disturbance regime responsible for shaping and reshaping ecosystems within the SFAN. The dominant geological force—plate movement along the San Andreas Fault—has created unusual habitats from Pinnacles to Point Reyes for a variety of species including endemics and edge-of-range species. Seismic activity continues to alter the geologic landscape and soils, impacting the associated biota. The El Niño-Southern Oscillation and the Pacific Decadal Oscillation, natural change processes influenced by a combination of weather, climatic events, and oceanographic processes affect precipitation patterns and drought conditions, thereby enhancing fire potential, all of which affect community composition, structure, and function. They also dramatically change coastal and oceanographic processes, resulting in significant disruption of the trophic food webs of the marine ecosystems.

Fire itself is a significant source of ecological change that has historically shaped ecosystems in the San Francisco area and continues to impact them currently (Moratto 1984). Sources of fire predominantly have been anthropogenic in nature, but wildfire has had a significant impact on SFAN ecosystems. The Vision wildfire in PORE in 1995 burned around 12,000 acres of land that had not likely been burned in over 60 years because of fire suppression. Several plant species are fire adapted and require this natural disturbance for renewal.

Coastal ecosystems are created and recreated by erosional and accretive forces that change coastal habitats subtly over time or rapidly and dramatically as in the case of major storm events. Erosion and deposition are a part of hydrologic disturbance regimes in freshwater ecosystems, too. Flooding events shape stream morphology, deposit and flush materials from riparian wetlands, and transport materials and organisms to downstream ecosystems. Hydrologic disturbance may open small patches for colonization or restructure entire stream channels over both the long term and the short term.

Disease, herbivory, and trampling serve as sources of biotic disturbance in the SFAN. Outbreaks of pine bark beetles, which can lead to pine pitch canker (*Fusarium subglutinans f.sp. pini*) infestations destroy individual trees or entire stands, opening gaps in the forest canopy to colonization by the same or other tree species (Adams 1989). Likewise, periodic surges in ungulate populations can lead to over browsing of herbaceous vegetation, altering competitive interactions among plants and changing species composition of plants and, indirectly, animals.

As a result of the interactions of these forces of natural disturbance, ecosystems in the SFAN are in a constant state of flux, creating significant natural variability at several spatial and temporal scales.

1.3.1.9 Anthropogenic Threats

With a current population of 7 million, the metropolitan centers of San Francisco, Oakland, and San Jose are forecast to have a population of 8 million by 2020 (Assoc. of Bay Area Governments 2000). As a result, anthropogenic stressors pose a significant threat to the integrity and sustainability of the SFAN park ecosystems. The degree of threat to these resources is a result of the parks' juxtaposition within the urban landscape and the extensive urban/ wildland interface within the parks.

The NPS Pacific West Region (PWR) identified several of the most important anthropogenic issues to parks of the region in 2002 that included habitat fragmentation, fire management issues, invasive species, global climate change, and water quality/quantity issues (PWR Science Meeting, July 2002). These are also the primary threats to the SFAN parks. Many of the threats are experienced by all of the SFAN parks to varying degrees, but threats are also park specific such as rock climbing at PINN (see Section 2.5: Description of Stressors).

Although the parks serve as refuges for many animal species, development external to the parks has fragmented the connection among parks and other areas of refuge. Consequently, large terrestrial mammals such as mountain lions that require large home ranges may experience difficulty moving from refuge to refuge. Recreational activities within the parks also exacerbate habitat fragmentation stresses. Intense human use of the parks is growing as the adjacent human population increasingly seeks recreational access to the parks for biking, hiking, kayaking, and hanggliding.

Years of fire suppression and adjacent land management practices have altered the wildlife habitat making it difficult to sustain populations of large predators such as bears, mountain lions, and coyotes. Poor fire timing and incorrect intensity of prescribed burns have converted entire vegetation communities, especially chaparral in PINN, to grassland (T. Leatherman pers. comm.) Additionally, post-fire bare ground often encourages the growth of non-native plants. Human safety concerns continue to require wildland fire suppression, especially where vegetation communities are in close proximity to human structures.

Invasive species, plant and animal, terrestrial and aquatic, are one of the most significant threats to the long-term sustainability of the parks' native ecosystems. One third of the 1200 plant species of GOGA, MUWO, and PORE are non-native. Feral pigs pose a major threat to native plants, displace native animals from traditional home ranges, degrade water quality, and threaten riparian habitats and species at PINN. Non-native deer and turkeys at PORE pose a serious threat to native plant and animal species. Poorly understood but likely very serious is the threat from non-native aquatic species. In San Francisco Bay, for example, 75% of the estuarine species from bivalves to marsh plants are non-native. Non-native species have been introduced to the area via bilge water from ships and aquaculture, through marshland restoration efforts (e.g., use of Atlantic cord grass by Army Corps of Engineers), and for sport fishing (e.g., striped bass). Introduction of non-native diseases also are an emerging issue. Sudden Oak Death (SOD) caused by an introduced pathogen has emerged in the San Francisco Bay Area centered in Marin County and is killing several tree species, primarily oaks. Animal diseases are also being documented in the area including Johne's disease, a paratuberculosis bacterium found in dairy cattle. This disease can infect native elk and deer populations.

Global Climate Change resulting from greenhouse gas accumulation in the atmosphere is expected to increase weather variability in unpredictable ways including droughts or increased precipitation. The SFAN is predicted to have increased rainfall, and more intense and more frequent El Niño-Southern Oscillation events. Sea level already has risen 4-8 inches in the past century, and models predict that this rise will accelerate, potentially rising from 5 to 37 inches over the next 100 years (NAST 2001). Climate change may impact shoreline erosion, saltwater intrusion in groundwater supplies, and inundation of wetlands and estuaries. These are vital resource management concerns along the 120 miles of the SFAN shoreline. Increased and more intense precipitation would also increase erosion and flood events at all of the parks, which are characterized by erodible soils. Sea temperature is also predicted to continue to rise. Central California waters have already increased in temperature over the past 30 years, with changes in the distribution of many marine species of invertebrates and fishes (Croll et al. 2000).

In the SFAN, water quality is a very high profile issue because of the network's proximity to a large urban area. Industrial, agricultural, and recreational pollution are threatening the water resources of the parks. The Norwalk virus, for example, which contaminated shellfish sickened over 100 people in Tomales Bay in 1998. Water transport and diversion are also significant stressors manifested in sediment deposition/erosion, accretive/ avulsive meandering, flow regimes (bankfull/dominant discharge/peak flow) based on channel forming flow, and long-shore sediment transport. As an example, many new vineyards around PINN with intensive irrigation requirements are increasing groundwater withdrawal rates.

In addition to the threats identified by the PWR, human activities in the San Francisco Bay Area have raised concerns over the effects of light pollution, air pollution, engineered structures, and other stressors on ecological integrity in the SFAN. The dominant anthropogenic threats in the SFAN are addressed in Section 2.5: Descriptions of Stressors.

1.3.1.10 Species of Special Concern

The SFAN's unique ecological setting and close proximity to urban development have combined to produce an environment that is home to a variety of species of special concern. These species include endemic, sensitive, rare, threatened, or endangered species recognized by federal, state, regional, and park authorities (Table 1.10). Simultaneously, environmental conditions and anthropogenic activities have created suitable pathways for invasion by exotic species, exasceerbating the stress on unique and at-risk species. Exotic species of concern also are listed in Table 1.10. Data were compiled from several sources (CalEPPC 1999, GOGA 1999, SFAN 2000, CNPS 2001, Jepson and Murdock 2002, PINN 2003, PORE 2003).

Table 1.10. Species of special concern in the San Francisco Bay Area Network. Included are species with sensitive, rare, threatened, or endangered status, exotic species, and other relevant species recognized by federal, state, and other authorities. Parks where these species may be found have been identified.

Scientific name	Common name	Federal	State	Other*	Park(s)
Mammals					
Aplodontia rufa	Point Reyes mountain beaver	(FSC)		CDFG: CSC	PORE
Arborimus pomo	Red tree vole	(FSC)		CDFG: CSC	PORE, GOGA
Bassaruscys astuts	Ringtail				GOGA, PORE, PINN
Dipodomys elephantinus	Big-eared kangaroo rat			CDFG: CSC	PINN
Neotoma fuscipes annectens	San Francisco dusky-footed woodrat	(FSC)		CDFG: CSC	GOGA
Reithrodontomys raviventris	Salt-marsh harvest mouse	FE	SE		PORE, GOGA
Zapus trinotatus orarius8	Point Reyes jumping mouse	(FSC)		CDFG: CSC	PORE, GOGA
Cervus nannodes	Tule elk				PORE
Canis latrans	Coyote				GOGA, PORE, PINN
Felis concolor	Mountain lion				GOGA, PORE, PINN
Taxidea taxus	American badger			CDFG: CSC	GOGA, PORE, PINN
Antrozous pallidus	Pallid bat			CDFG: CSC FS: Sensitive BLM: Sensitive WBWG: High Priority	PORE, GOGA, PINN
Eumops perotis californicus	Greater western mastiff bat	(FSC)		CDFG: CSC BLM: Sensitive WBWG: High Priority	GOGA, PINN
Myotis evotis	Long-eared myotis bat	(FSC)		BLM: Sensitive	PORE, GOGA, PINN
Myotis volans	Long-legged myotis bat	(FSC)		WBWG: High Priority	PORE, GOGA, PINN
Myotis yumanensis	Yuma myotis bat	(FSC)		CDFG: CSC BLM: Sensitive	PORE, GOGA, PINN
Myotis thysanodes	Fringed myotis bat	(FSC)		BLM: Sensitive WBWG: High Priority	PORE, GOGA, PINN
Myotis subulatus	Small-footed myotis bat	(FSC)		BLM: Sensitive	PORE, PINN
Plecotus townsendii townsendii	Townsend's western big-eared bat	(FSC)		CDFG: CSC FS: Sensitive BLM: Sensitive WBWG: High Priority	PORE, GOGA, PINN
Arctocephalus townsendi	Guadalupe fur seal	FT		MMPA	PORE
Callorhinus ursinus	Northern fur seal	(FSC)		MMPA	PORE
Enhydra lutris nereis	Southern sea otter	FT		MMPA	GOGA, PORE
Eumetopias jubatus	Steller sea lion	FT		MMPA	GOGA, PORE
Mirounga angustirostris	Elephant seal			MMPA	PORE
Phoca vitulina richardii	Harbor seal			MMPA	GOGA, PORE
Balaenoptera musculus	Blue whale	FE		MMPA	GOGA, PORE
Balaenoptera physalus	Finback whale	FE		MMPA	GOGA, PORE
Eschrictus robustus	Gray whale	FD		MMPA	GOGA, PORE
Megptera novaeangliae	Humpback whale	FE		MMPA	GOGA, PORE
Physeter catodon	Sperm whale	FE		MMPA	PORE
Zalophus californianus	California sea lion			MMPA	GOGA, PORE
Amphibians/Reptiles					
Ambystoma californiense	California tiger salamander	FC		CDFG: CSC CDFG: Protected	PINN
Anniella pulchra	Silvery legless lizard	(FSC)		CDFG: CSC FS: Sensitive	PINN
Clemmys marmorata	Western pond turtle	(FSC)		CDFG: CSC CDFG: Protected	GOGA, PORE, PINN
Clemmys marmorata	Southwestern pond turtle	(FSC)		CDFG: CSC CDFG: Protected FS: Sensitive BLM: Sensitive	PINN
Chelonia mydas	Common green sea turtle	FT			PORE

Scientific name	Common name	Federal	State	Other*	Park(s)
Chelonia agassizii	Black sea turtle	FT			PORE
Caretta caretta	Loggerhead sea turtle	FT			PORE
Dermochelys coriacea	Leatherback sea turtle	FE			PORE
Lepidochelys olivacea	Olive Ridley sea turtle				PORE
Masticphis flagellum	San Joaquin whipsnake	(FSC)		CDFG: CSC CDFG: Protected	PINN
Phrynosoma coronatum	California (Coast) horned lizard	(FSC)		CDFG: CSC	PINN
Rana aurora draytoni	California red-legged frog	FT		CDFG: CSC CDFG: Protected	GOGA, PORE, PINN
Thamnophis hammondii	Two-striped garter snake			CDFG: CSC CDFG: Protected	PINN
Thamnophis sirtalis tetrataenia	San Francisco garter snake	FE			GOGA
Fish					
Acipenser medirostris	Green sturgeon	(FSC)		CDFG: CSC	PORE, GOGA
Eucyclogobius newberryi	Tidewater goby	FE			PORE, GOGA
Engraulis mordax	Northern anchovy			CDFG: Harvested	PORE, GOGA
Gasterosteus aculeatus williamsonii	Threespine stickleback	FE			PORE
Oncorhynchus tshawytscha	Chinook salmon	FE	SE		PORE, GOGA
Oncorhynchus kisutch	Coho salmon	FT			PORE, GOGA
Oncorhynchus mykiss	Steelhead	FT			PORE, GOGA
Pogonichthys macrolepidotus	Sacramento splittail	FT			PORE
Sebastis paucispinis	Boccacio			CDFG: CSC	PORE, GOGA
Carchadon carcharias	Great White Shark			CDFG: Protected	PORE, GOGA
Clupea pallasii	Pacific herring			CDFG: harvested	PORE, GOGA
Birds					
Accipiter cooperii	Cooper's hawk			CDFG: CSC	PINN, GOGA, PORE, JOMU
Accipiter striatus	Sharp-shinned hawk			CDFG: CSC	PINN, GOGA, PORE, JOMU
Agelaius tricolor	Tri-colored blackbird	(FSC)		CDFG: CSC FWS: MNBMC Audubon: Cal WL	PORE, GOGA
Aquila chrysaetos	Golden eagle			CDFG: CSC CDFG: Fully Protected CDF: Sensitive	PINN, PORE
Asio otus	Long-eared owl			CDFG: CSC	PINN
Brachyramhus marmoratus marmora	Marbled murrelet	FT			PORE, GOGA
Branta canadensis	Aleutian Canada goose	FE			PORE
Buteo regalis	Ferruginous hawk	(FSC)			GOGA, PORE, JOMU
Buteo swainsoni	Swainson's hawk		ST		GOGA, PORE
Cantopus cooperi	Olive-sided flycatcher			Audubon: Cal WL FWS: MNBMC	GOGA, PINN, PORE
Caruelis lawrencei	Lawrence's goldfinch			PIF: Watch List FWS: MNBMC Audubon: Cal WL	PINN, JOMU
Cerorhinca monocerata	Rhinoceros auklet			CDFG: CSC	PORE, GOGA
Charadruis alexandrinus nivosus	Western snowy plover	FE	SE		GOGA, PORE
Crus canadensis tubida	Greater sandhill crane	FT			PORE
Diomedea albatrus	Short-tailed albatross	FE			PORE
Elanus leucurus	White-tailed kite			CDFG: Fully Protected	PINN, JOMU, PORE, GOGA
Empidonax traillii	Willow flycatcher	ST			GOGA, PORE
Falco mexicanus	Prairie falcon			CDFG:CSC Audubon: Cal WL	PINN, PORE
Falco peregrinus anatum	American peregrine falcon	FE	SE	FWS: MNBMC CDF: Sensitive CDFG: Fully Protected	GOGA, PINN, PORE
Gavia immer	Common loon			CDFG: CSC	GOGA, PORE
Geothlypis trichas	Saltmarsh common yellowthroat	(FSC)		CDFG: CSC	PORE, GOGA
Gymnogyps californianus	California condor	FE	SE		PINN
Haliaeetus leucocephalus	Bald eagle	FT			GOGA, PORE
Icteria virens	Yellow-breasted chat			CDFG: CSC FWS: MNBMC	PINN
Larus californicus	California gull			CDFG: CSC	GOGA, PORE

Scientific name	Common name	Federal	State	Other*	Park(s)
Oceanodroma homochroa	Ashy storm-petrel	(FSC)		CDFG: CSC FWS: MNBMC PIF: Watch List	PORE
Pelecanus occidentalis californicus	California brown pelican	FE	SE		GOGA, PORE
Phalacrocorax auritus	Double-crested cormorant			CDFG:CSC	GOGA, PORE
Rallus longirostris obsoletus	California clapper rail	FE			GOGA, PORE
Riparia riparia	Bank swallow	ST			GOGA, PORE
Sterna antillarum	Least tern	FE	SE		GOGA, PORE
Strix occidentalis caurina	Northern spotted owl	FT			PORE, GOGA
Invertebrates					
Callophrys mossii bayensis	San Bruno elfin butterfly	FE			GOGA
Euphydryas editha bayensis	Bay checkerspot butterfly	FT			GOGA
Haliotes cracherodii	Black abalone				PORE
Icaricia icariodes missionensis	Mission blue butterfly	FE			GOGA
Speyeria zerene myrtleae	Myrtle silverspot butterfly	FE			PORE
Syncaris pacifica	California freshwater shrimp	FE			GOGA, PORE
Exotic Animals					
Axis axis	Axis deer				PORE
Carcinus meanas	Europen green crab				GOGA, PORE
Corbicula fluminea	Asian clams				GOGA, PORE
Dama dama	Fallow deer				PORE
Dreissena polymorpha	Zebra mussels				GOGA, PORE
Eriocheir sinensis	Chinese mitten crab				GOGA, PORE
Felis domesticus	Feral cats				ALL
Meleagris gallopavo	Wild turkey				ALL
Molothrus ater	Brown headed cowbird				GOGA, PORE
Passer domesticus	House sparrow				ALL
Rana catesbeiana	Bullfrog				PORE, GOGA
Sturnus vulgaris	European starling				ALL
Sus scrofa	Feral pig				PINN
Vulpes fulva	Red fox				ALL
Vascular Plants - rare					
Abronia umbellata ssp. breviflora	Pink Sand-verbena	(FSC)		CNPS: 1B (2-3-2)	PORE
Acanthomintha ovata duttonii	San Mateo thornmint	FE	SE	CNPS: 1B (3-3-3)	GOGA
Agrostis blasdalei	Blasdale’s bent grass	(FSC)		CNPS: 1B (3-2-3)	PORE
Alopecurus aequalis sonomensis	Sonoma alopecurus	FE			PORE
	Point Reyes bent grass	(FSC)			PORE
Arabis blepharophylla	Coast rock cress			CNPS: 4 (1-1-3)	PORE, GOGA, PRES
Arctostaphylos hookeri montana	Mt. Tamalpais manzanita	(FSC)		CNPS: 1B (3-1-3)	GOGA
Arctostaphylos hookeri ravenii	Presidio manzanita	FE	SE		PRES
Arctostaphylos montaraensis	Montara manzanita	(FSC)		CNPS: 1B (3-2-3)	GOGA
Arctostaphylos virgata	Marin manzanita			CNPS: 1B (2-2-3)	PORE, GOGA
Astragalas pycnostacyus	Coastal marsh milk-vetch			CNPS: 1B (3-2-3)	PORE
Blennosperma nanum var. robustum	Point Reyes blennosperma	(FSC)	SR	CNPS: 1B (3-2-3)	PORE
Calamagrostis crassiglumis	Thurber’s reed grass	(FSC)		CNPS: 2 (3-3-1)	PORE
Calochortus umbellatus	Oakland Star-tulip			CNPS: 4 (1-2-3)	GOGA
Campanula californica	Swamp harebell	(FSC)		CNPS: 1B (2-2-3)	PORE
Carex buxbaumii	Buxbaum’s sedge			CNPS: 4 (1-2-1)	PORE
Castelleja affinis neglecta	Tiburon Indian paintbrush	FE	ST	CNPS: 1B (3-2-3)	GOGA, PORE
Ceanothus gloriosus var. exultatus	Glory brush			CNPS: 4 (1-1-3)	GOGA
Ceanothus gloriosus var. gloriosus	Point Reyes ceanothus			CNPS: 4 (1-1-3)	PORE, GOGA
Ceanothus gloriosus var. porrectus	Mt. Vision ceanothus	(FSC)		CNPS: 1B (3-1-3)	PORE
Ceanothus masonii	Mason’s ceanothus	(FSC)	SR	CNPS: 1B (3-2-3)	GOGA
Chorizanthe cuspidata var. cupsidata	San Francisco Bay spineflower	(FSC)		CNPS: 1B (2-2-3)	PORE, GOGA, PRES
Chorizanthe cuspidata var. villosa	Woolly-headed spineflower			CNPS: 1B (3-2-3)	PORE

Scientific name	Common name	Federal	State	Other*	Park(s)
Chorizanthe douglassii	Douglas's spineflower			CNPS: 4 (1-1-3)	PINN
Chorizanthe robusta	Robust spineflower	FE			PORE
Chorizanthe valida	Sonoma spineflower	FE			PORE
Cirsium fontinale fontinale	Fountain thistle	FE	SE	CNPS: 1B (3-3-3)	GOGA
Cirsium andrewsii	Franciscan thistle			CNPS: 1B (2-2-3)	PORE, GOGA, PRES
Collinsia corymbosa	Round-headed Chinese houses	(FSC)		CNPS: 1B (2-2-3)	PORE, PRES
Clarkia breweri	Brewer's clarkia			CNPS: 4 (1-2-3)	PINN
Clarkia franciscana	Presidio clarkia	FE	SE	CNPS: 1B (3-3-3)	GOGA, PRES
Cordylanthus maritimus ssp. palustris	Point Reyes bird's beak, Saltmarsh bird's beak	(FSC)		CNPS: 1B (2-2-2)	PORE, GOGA, PRES
Delphinium californicum ssp. interius	Coast larkspur			CNPS: 1B (3-2-3)	PINN
Dirca occidentalis	Western leatherwood			CNPS: 1B (2-2-3)	GOGA
Elymus californicus	California bottlebrush grass			CNPS: 4 (1-1-3)	PORE, GOGA
Eriastrum virgatum	Virgate eriastrum			CNPS: 1B (2-2-3)	PINN
Eriogonum nortonii	Pinnacles buckwheat			CNPS: 1B (2-1-3)	PINN
Eriogonum nudem var. indictum	Protruding buckwheat			CNPS: 4 (1-2-3)	PINN
Eriophyllum latilobum	San Mateo wooly sunflower	FE	SE	CNPS: 1B (3-3-3)	GOGA
Eriogonum luteolum var.caninum	Tiburon buckwheat			CNPS: 3 (?-2-3)	GOGA
Erysimum franciscanum	San Francisco wallflower	(FSC)		CNPS: 4 (1-2-3)	GOGA, PRES
Eschscholzia hypecoides	San Benito poppy			CNPS: 4 (1-1-3)	PINN
Fritillaria lanceolata var. tristulis	Marin checker lily			CNPS: 1B (3-3-3)	PORE
Fritillaria liliaceae	Fragrant fritillary	(FSC)		CNPS: 1B (2-2-3)	PORE, GOGA
Gilia capitata ssp. chamissonia	Dune gilia			CNPS: 1B (2-3-3)	PORE, GOGA, PRES
Gilia millefoliata	Dark-eyed gilia			CNPS: 1B (2-2-2)	PORE
Grindelia hirsutula var. maritima	San Francisco gumplant	(FSC)		CNPS: 1B (2-2-3)	PORE, GOGA, PRES
Helianthella castanea	Diablo sunflower	(FSC)		CNPS: 1B (2-2-3)	JOMU
Hemozonia congesta ssp leucocephala	White hayfield tarplant			CNPS: 3 (?-?-3)	PORE
Hersperevax sparsifora var brevifolia	Short-leaved evax	(FSC)		CNPS: 2 (2-2-1)	PORE, PRES
Hesperolinon congestum	Marin western flax, Marin dwarf flax	FT	ST	CNPS: 1B (3-3-3)	GOGA, PRES
Horkelia cuneata ssp.sericea	Kellogg's horkelia	(FSC)		CNPS: 1B (3-3-3)	PORE, PRES
Horkelia marinensis	Point Reyes horkelia	(FSC)		CNPS: 1B (3-2-3)	PORE
Horkelia cuneata ssp. sericea	Wedgeleaf horkelia				PORE
Juglans californica var. hindsii	California black walnut	(FSC)		CNPS: 1B (3-3-3)	JOMU, EUON
Lasthenia macrantha ssp macrantha	Perennial goldfields			CNPS: 1B (2-2-3)	PORE
Layia carnosa	Beach layia	FE	SE	CNPS: 1B (3-3-3)	PORE
Lessingia arachnoidea	Crystal springs lessingia	(FSC)		CNPS: 1B (3-2-3)	GOGA
Lessingia germanorum	San Francisco lessingia	FE	SE	CNPS: 1B (3-3-3)	GOGA, PRES
Lessingia tenuis	Spring lessingia			CNPS: 4 (1-1-3)	PINN
Lilium maritimum	Coast lily	(FSC)		CNPS: 1B (2-3-3)	PORE
Limnanthes douglasii ssp. sulphurea	Point Reyes meadowfoam	(FSC)	SE	CNPS: 1B (3-2-3)	PORE
Limosella subulata	Delta mudwort			CNPS: 2 (2-3-1)	PORE
Linanthus ambiguus	Serpentine linanthus				GOGA
Linanthus grandiflorus	Large-flowered linanthus			CNPS: 4 (1-2-3)	PORE
Linanthus rosaceus	Rosy linanthus			CNPS: 1B (3-3-3)	PORE
Lupinus eximius	San Mateo tree lupine	(FSC)		CNPS: 3 (2-2-3)	GOGA
Lupinus tidestromii	Tidestrom's lupine	FE	SE	CNPS: 1B (3-3-3)	PORE
Malacothamnus aboriginum	Indian valley bush mallow			CNPS: 1B (2-2-3)	PINN
Malacothamnus fasciulatus	Santa Cruz Island bush mallow	FE	SE	CNPS: 1B (3-3-3)	GOGA
Microseris paludosa	Marsh microseris			CNPS: 1B (2-2-3)	PORE
Mondardella undulata	Curly-leaved monardella			CNPS: 4 (1-2-3)	PORE
Navarretia jaredii	Paso Robles navarretia			CNPS: 4 (1-1-3)	PINN
Nemacladus gracilis	Slender nemacladus			CNPS: 4 (1-1-3)	PINN
Pentachaeta bellidiflora	White-rayed	FE	SE	CNPS: 1B (3-3-3)	GOGA

Scientific name	Common name	Federal	State	Other*	Park(s)
	pentachaeta				
Perideridia gairdneri var gairdneri	Gairdner's yampah	(FSC)		CNPS: 4 (1-2-3)	PORE
Phacelia insularis var. continentis	North Coast phacelia	(FSC)		CNPS: 1B (3-2-3)	PORE
Piperia elegans ssp. decurtata	Point Reyes rein orchid			CNPS: 1B (3-3-3)	PORE
Plagiobothrys chorisianus	Choris's popcorn-flower			CNPS: 1B (2-2-3)	GOGA
Plagiobothrys diffusus	San Francisco popcorn-flower	(FSC)	SE	CNPS 1B (3-3-3)	PORE
Plagiobothrys uncinatus	Hooked popcorn-flower	(FSC)		CNPS: 1B (2-2-3)	PINN
Pleuropogon refractus	Nodding semaphore grass			CNPS: 4 (1-2-1)	PORE
Polygonum marinensis	Marin knotweed	(FSC)		CNPS: 3 (3-3-3)	PORE
Ranunculus lobbii	Lobb's aquatic buttercup			CNPS: 4 (1-2-3)	PORE
Sidalcea calycosa ssp. rhizomata	Point Reyes checkerbloom			CNPS: 1B (2-2-3)	PORE
Silene verecunda spp. verecunda	San Francisco campion	(FSC)		CNPS: 1B (3-2-3)	PRES
Stebbinsoseris decipiens	Santa Cruz microseris	(FSC)		CNPS: 1B (2-2-3)	PORE, GOGA
	Beach starwart			CNPS: 4 (1-2-3)	PORE
Streptanthus glandulosus ssp. pulchellus	Tamalpais jewel-flower	(FSC)		CNPS: 1B (3-1-3)	GOGA
Suaeda californica	California seablite	FE		CNPS: 1B (3-3-3)	GOGA, PRES
Tanacetum camphoratum	Dune tansy	(FSC)			GOGA
Trifolium amoenum	Showy Indian clover	FE			PORE (extirpated), GOGA
Triteleia lugens	Coast range triplet lily			CNPS: 4 (1-1-3)	PINN
Triphysaria floribunda	San Francisco owl's clover	(FSC)		CNPS: 1B (2-2-3)	PORE, GOGA, PRES
<u>Exotic Plants</u>					
Acacia melanoxylon	Blackwood acacia			CalEPPC: NMI PORE/GOGA: B-1	PORE, GOGA
Ailanthus altissima	Tree of heaven			CalEPPC: A-2	JOMU
Amophilla arenaria	European beach grass			CalEPPC: A-1 PORE: A-2 GOGA: B-1	PORE, GOGA
Arctotheca calendula	Capeweed		A	CalEPPC: Red Alert PORE/GOGA: A-1	PORE, GOGA
Arundo donax	Giant reed			CalEPPC: A-1	JOMU
Bellardia trixago	Bellardia			CalEPPC: B	GOGA, JOMU
Brassica nigra	Black mustard			CalEPPC: B	JOMU, PINN
Carduus acanthoides	Giant plumeless thistle		A	CalEPPC: NMI PORE: A-1	PORE
Carduus pycnocephalus	Italian thistle			CalEPPC: B	JOMU
Carpobrotus edulis	Iceplant			CalEPPC: A-1 PORE/GOGA: A-2	PORE, GOGA
Carthamus lanatus	Distaff thistle		B	PORE: A-1	PORE
Centaurea calcitrapa	Purple-star thistle		B	CalEPPC: B PORE/GOGA: A-1	PORE, GOGA, JOMU
Centaurea melitensis	Napa thistle, Tocalote			CalEPPC: B PORE: A-1	PORE, PINN
Centaurea solstitialis	Yellow star thistle		C	CalEPPC: A-1 PORE/GOGA: A-1	PORE, GOGA, PINN
Cirsium vulgare	Bull thistle			CalEPPC: B	All
Conium maculatum	Poison hemlock			CalEPPC: B	All
Cortaderia jubata	Pampas grass			CalEPPC: A-1	PORE, GOGA
Cotoneaster ssp.	Cotoneaster			CalEPPC: NMI PORE/GOGA: B-1	PORE, GOGA, JOMU
Cynara cardunculus	Artichoke thistle			CalEPPC: A-1	JOMU
Cytisus scoparius	Scotch broom			CalEPPC: A-1	GOGA, PORE
Cytisus striatus	Striated broom			CalEPPC: A-2	GOGA
Ehrharta calycina	Veldt grass			CalEPPC: B PORE: A-2 GOGA: A-2/NMI	PORE, GOGA
Eucalyptus globulus	Tasmanian blue gum			CalEEPC: A-1	PORE, GOGA, JOMU
Festuca arundinacea	Tall fescue			CalEPPC: B	PORE, GOGA

Scientific name	Common name	Federal	State	Other*	Park(s)
				PORE: A-2 GOGA: A-2/NMI	
Foeniculum vulgare	Fennel			CalEPPC: A-1 PORE: B-2 GOGA: A-2	PORE, GOGA, JOMU
Genista monspessulana	French broom			CalEPPC: A-1	PORE, GOGA, JOMU
Helichrysum petiolare	Helichrysum			CalEPPC: Red Alert PORE: A-1	PORE
Hirschfeldia incana	Summer mustard			CalEPPC: NMI	PINN
Holcus lanatus	Velvet grass			PORE: B-2/Red Alert GOGA: A-2/NMI	PORE, GOGA
Lathyrus latifolius	Perennial pea			PORE/GOGA: B-1	PORE, GOGA
Lepidium latifolium	Perennial pepperweed			CalEPPC: A-1	JOMU
Leucanthemum vulgare	Ox-eye daisy			CalEPPC: B PORE/GOGA: A-2	PORE, GOGA
Marrubium vulgare	Horehound				PINN
Mentha pulegium	Pennyroyal			CalEPPC: A-2	PORE, GOGA
Nicotiana glauca	Tree tobacco				PINN
Olea europaea	Olive			CalEPPC: B	JOMU
Phalaris aquatica	Harding grass			CalEPPC: B PORE: B-2 GOGA: A-2/NMI	PORE, GOGA, JOMU
Rubus discolor	Himalayan blackberry			CalEPPC: A-1	All
Senecio mikanioides	Cape ivy			CalEPPC: A-1	PORE, GOGA
Spartina alterniflora	Smooth cordgrass			CalEPPC: A-2	PORE, GOGA
Ulex europaeus	Gorse		B	CalEPPC: A-1 PORE/GOGA: A-1	PORE, GOGA
Verbascum blattaria	Moth mullein				PINN
Vinca major	Periwinkle			CalEPPC: B PORE/GOGA: B-2	PORE, GOGA, JOMU
<u>Lichens</u>					
Cladonia thiersii				CNPS: 4 (2-2-3)	PORE
Lecanora phryganitis				CNPS: 4 (1-1-3)	PORE
Teloschistes exilis				CNPS: 1B (3-3-3)	GOGA
Teloschistes flavicans				CNPS: 1B (3-2-3)	PORE
Texosporium sancti-jacobi,				CNPS: 2 (3-3-2)	PINN
Verrucaria tavaresiae				CNPS: 1B (3-3-3)	GOGA

Federal and State Listing Status
FC = Federal Candidate Species; FD = Federally Delisted; FE = Federally Endangered; FSC = Federal Species of Concern – former Category 2 canidates (no longer an active, legal term); FT = Federally Threatened; SE = State Endangered; ST = State Threatened; SR = State Rare.

Exotic Plant Listings
CA Department of Food and Agriculture Status, Pest Ratings of Noxious Weed Species and Noxious Weed Seed: A = Limited distribution within the State. Eradication, quarantine or other holding action at the State county level is required. Quarantine interceptions to be rejected or treated at any point within the State. B = More common distribution within the State. Intensive control or eradication, where feasible, at the county level. C = Generally widespread. Control or eradication, as local conditions warrant, at the discretion of the County Agricultural Commissioner.
CalEPPC = California Exotic Pest Plant Council Status: A-1 = Most Invasive Wildland Pest Plants, Widespread; A-2 = Most Invasive Wildland Pest Plants, Regional; B = Wildland Pest Plants of Lesser Invasiveness; Red Alert = Species with potential to spread explosively, infestations currently restricted; NMI: Need More Information.
PORE / GOGA Exotic Plant Ranking Status: A-1 = Most Invasive Pest Plants: all populations eradicated when possible; A-2 = Most Invasive Pest Plants: widespread within park, large populations contained, or controlled where threatening special status species or rare habitat, or opportunistically removed when in the field for other reasons; B-1 Pest Plants of Lesser Invasiveness: present in small populations, eradicated when possible; B-2 Pest Plants of Lesser Invasiveness: widespread within park, controlled only where threatening special status species or rare habitat, or opportunistically removed when in the field for other reasons; Red Alert: Species with potential to spread explosively, infestations currently restricted; NMI = Need more information.

***Other Status Listings**
CDFG = CA Department of Fish and Game, CSC (California Species of Special Concern—Protected, Fully Protected); **FWS** = US Fish and Wildlife Service, MNBMC (Migratory Nongame Birds of Management Concern); **FS** = US Forest Service—Sensitive; **CDF** = CA Department of Forestry—Sensitive; **BLM** = Bureau of Land Management—Sensitive; **MMPS** = Marine Mammal Protection Act; **WBWG** = Western Bat Working Group—High Priority; **Audubon** = National Audubon Society, Cal WL (California Watch List); **PIF** = Partners in Flight—Watch List; **CNPS** = California Native Plant Society [(<u>Listing Significance</u>—List 1B = Plants Rare, Threatened, or Endangered in California and Elsewhere, List 2 = Plants Rare, Threatened,

or Endangered in California, but More Common Elsewhere, List 3 = Plants About Which We Need More Information - A Review List, List 4 = Plants of Limited Distribution - A Watch List.) (R-E-D Code (Rarity-Endangerment-Distribution)—*Rarity*: 1 = Rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time, 2 = Distributed in a limited number of occurrences, occasionally more if each occurrence is small, 3 = Distributed in one to several highly restricted occurrences, or present in such small numbers that it is seldom reported. *Endangerment*: 1 = Not endangered, 2 = Endangered in a portion of its range, 3 = Endangered throughout its range. *Distribution*: 1 = More or less widespread outside California, 2 = Rare outside California, 3 = Endemic to California.)]

1.3.2 Management Objectives, Issues, and Monitoring Questions for Network Parks

1.3.2.1 Management Objectives

Each park was established to protect and preserve unique natural and cultural resources contained within its boundaries while providing for public enjoyment of these resources. Park-enabling legislation and other relevant documents such as Resource Management Plans direct park managers to identify management goals necessary to fulfill the park's founding purposes (Appendix 5). Management goals, in turn, necessitate more specific management objectives. Management objectives and matching park resources need to be considered together for a monitoring plan to be successful and for the park to meet the overall goal of conservation. Table 1.11 lists the management objectives identified for the SFAN parks.

Table 1.11. Management objectives for the San Francisco Bay Area Network parks. Management objectives from enabling legislation are listed for all parks.

Park	**Management Objectives**
Eugene O'Neill NHS	• Achieve an understanding of the natural ecosystem existing on the site prior to the O'Neill's arrival, the remnants of that ecosystem today, and preserve, protect, and interpret the natural scene associated with the estate during O'Neill's tenure. • Enhance conservation efforts of Las Trampas Regional Wilderness Area surrounding the site. • Contain or eliminate non-native invasive plants. • Evaluate the risk of and manage Sudden Oak Death.
Golden Gate NRA*	• Maintain the primitive and pastoral character of the parklands in northern Marin County. • Maintain and restore the character of natural environmental lands by maintaining the diversity of native park plant and animal life, identifying and protecting threatened and endangered species, marine mammals, and other sensitive natural resources, controlling exotic plants and checking erosion whenever feasible. • Locate development in areas previously disturbed by human activity whenever possible.
John Muir NHS	• Protect the natural scene associated with John Muir's days at the ranch. • Identify, monitor and manage the flora and fauna of the Mt. Wanda area. • Protect sensitive species. • Manage human and animal impacts on park natural resources. • Contain or eliminate non-native invasive plants.

Park	Management Objectives
Pinnacles NM	• Maintain the primitive character of the wilderness. • Preserve natural ecologic and geologic processes (e.g. fire, flood, mass wasting). • Maximize native species, assemblages, communities and ecosystems across a variety of temporal and spatial scales. • Provide for the scientific study of natural processes and species. • Recognize and allow for the natural range of variability, while promoting ecosystem resilience, incorporating adaptive management strategies. • Control and eradicate, when practical, non-native species.
Point Reyes NS	• Identify, protect, and perpetuate the diversity of existing ecosystems, which are representative of the California seacoast. • Preserve and manage wilderness. • Protect marine mammals, threatened and endangered species, and other sensitive natural resources found within the seashore. • Retain research natural area status for the Estero de Limantour and the Point Reyes Headlands. • Manage seashore activities in the pastoral and estuarine areas in a manner compatible with resource carrying capacity. • Monitor grazing and improve range management practices in the pastoral zone in cooperation with the ranchers and the Natural Resource Conservation Service. • Enhance knowledge and expertise of ecosystem management through research and experimental programs that provide sound scientific information to guide management relating to wildlife, prescribed burning techniques, exotic plant and animal reduction, regulation and control of resource use, and pollution control. • Monitor mariculture operations, in particular, the oyster farm operation in Drakes Estero, in cooperation with the California Department of Fish and Game.

* includes all parks administered by Golden Gate NRA.

These objectives are compatible with a multi-faceted approach to monitoring natural resources that addresses specific management issues, focal species, and key properties and processes of ecosystem integrity. Collectively, individual park management objectives form the basis of the SFAN's management issues and monitoring questions.

1.3.2.2 Management Issues, Monitoring Questions, and Potential Indicators

The PWR, which includes the SFAN, has identified habitat fragmentation, water quality degradation, global climate change, endangered or sensitive species protection, non-native species invasions, fire management, and lack of scientific knowledge as the greatest issues facing ecosystem integrity in the region's national parks (PWR Science Needs Workshop 2002). The SFAN altered this list to reflect those natural resource issues that are most pertinent to the network. Input from Resource Management Plans, internal and external reviewers, and Vital Signs scoping workshops contributed to the list of management issues and monitoring questions in Table 1.12. Monitoring questions, in turn, have helped the SFAN identify potential indicators that may suitably address the monitoring questions related to the various management issues. An extensive list of monitoring questions and corresponding potential indicators identified by the network can be found in Appendix 7. The SFAN intends to maintain and expand existing monitoring partnerships (see Section 1.4) so that the network can efficiently and effectively tackle its management issues.

Table 1.12. Monitoring questions and potential indicators related to management issues for the San Francisco Bay Area Network parks.

Management Issue	Sample Monitoring Questions	Potential Indicators
Climate Change	How is climate and weather changing over time? What impact does this have on biotic and abiotic resources?	Weather/Climate
Air Quality Degradation	Is air quality degrading? Where, why and at what rate of change? What impact does this have on biotic and abiotic resources?	Air Quality
Water Quality Degradation	What are the baseline levels of contaminants? What are the natural ranges of core elements, metals, nutrients, and bacteria?	Water Quality—clarity, pathogenic bacteria, contaminants, MBAS/ caffeine
Water Quantity Alteration	Are water storage levels in existing aquifers decreasing? Are there groundwater impacts on riparian habitat and wildlife?	Groundwater Dynamics
Human Population Increase	Where is the natural dark night sky affected by light? Is this changing over time? What impact does this have on biotic resources? Are airplane overflights increasing over the park, affecting natural quiet?	Light Quality/Quantity Noise Levels
Land Use Change/Development	Which external activities are altering terrestrial habitat most significantly?	Plant Community Change-Multiple Scales
Resource Extraction	How are commercial and recreational fisheries affecting marine resources?	Estuarine and Marine Fish
Soil Alteration	What effects do engineered structures and other anthropogenic stresses have on soil structure, texture and chemistry?	Soil Structure, Texture and Chemistry
Nutrient Enrichment	What are the effects of ranching on surrounding ecosystems? What are the effects of farming on surrounding ecosystems?	Riparian Habitat
Park Development and Operations	How are park activities affecting geophysical processes?	Riparian Habitat
Recreational Use	Are recreational activities affecting birds of prey? Are recreational activities affecting breeding harbor seals?	Raptors—breeding Harbor seals–breeding
Fire Management	How is the distribution and occurrence frequency, intensity or magnitude of wildland fire changing over time? What impact does this have on biotic and abiotic resources?	Catastrophic Events Documentation—Wildland Fire
Non-native Invasive Species/ Disease	What non-native taxa are present and how are they affecting distribution and abundance of other species in rocky	Rocky Intertidal Community; Non-native plant and animal

Management Issue	Sample Monitoring Questions	Potential Indicators
	intertidal communities?	species
Native Species Decline and Extirpation	How is habitat fragmentation affecting the viability of rare plant populations? Are some species becoming genetically isolated? Are isolated populations suffering from inbreeding depression?	Federally Threatened and Endangered (T&E) Plant Species

Descriptions of the predominant drivers and stressors associated with these issues are included in Chapter 2: Conceptual Models and discussed in the workshop summaries (Appendices 1, 2, 3, and 4). Specific research to address these overarching management issues are presented in the Science Needs web site for the SFAN (http://www.nps.gov/pore/science.htm). Science needs fall into fifteen categories ranging from defining desired future conditions to developing non-native species controls:

- Ecosystem Monitoring,
- Landscape Ecology,
- Declining, Rare, Endangered and Sensitive Species,
- Water Quality/Quantity,
- Aquatic Ecology,
- Marine Ecology,
- Plant Ecology,
- Wildlife Ecology,
- Wilderness Management,
- Social Science,
- Fire Ecology,
- Restoration Ecology,
- Invasive Species,
- Geology, and
- Paleoecology.

1.3.2.3 Water Resources Monitoring Efforts and Questions, and Potential Indicators

Water Quality Planning meetings have been conducted for each park or group of parks (GOGA/MUWO, PRES, PINN, JOMU/EUON, and PORE). A list of discussion questions was addressed at each meeting to determine park priorities, issues, and data needs. Information gathered from these meetings (and from the SFAN Vital Signs Workshop in March 2003) was used to develop water quality monitoring questions (Appendix 6) and contribute to the list of potential indicators. Development of specific questions was found to be difficult without a complete analysis of all data. As data are analyzed, monitoring questions will become more refined.

The desired future condition is for water parameters to vary within natural ranges. However, there are conditions where this is currently not feasible. In those cases, the objective would be to see improved (not degraded) water quality over time. Therefore, the two key objectives are to:

- Reduce impairment of listed water bodies. The National Park Service goal (per the GPRA) is for 85% of park units to have unimpaired water quality by September 30, 2005.

- And, maintain high water quality where it exists.

Based on these objectives, four monitoring questions were generated from the Water Quality Planning meetings:

1. Are the data useful in guiding management decisions?
2. What is our level of compliance with beneficial uses?
3. What are the existing levels of X, Y, and Z? (Baseline data are needed.)
4. What are the natural ranges in values of X, Y, and Z? (Long-term data are needed.)

Similarly, meeting participants recommended the following potential indicators for monitoring water resources:

- Water Quality (core parameters: temperature, pH, dissolved oxygen, conductivity),
- Water Clarity (sediment and turbidity),
- Nutrients (Total N and Total P for marine systems baseline, ammonia for freshwater systems),
- Metals (baseline),
- Pathogenic Bacteria,
- Benthic Macroinvertebrates,
- Oil/Hydrocarbons,
- HAB (Harmful Algal Blooms),
- Surface Water Dynamics (flow, discharge, use),
- Groundwater Dynamics (water table, recharge, drawdown, use),
- Oceanographic Physical Parameters (sea level, currents, upwelling),
- Flooding,
- Waves, and
- Drought.

1.4 Status of Monitoring Programs in and Adjacent to the SFAN Parks

1.4.1 Summary of Relevant Historical, Current, and Potential Monitoring Programs

Monitoring programs currently exist for some of the parks under previously developed Vital Signs models that include marine, freshwater, and terrestrial plant and vertebrate components as well as abiotic components. Several threatened or endangered (T&E) species, plant communities, water quality, air quality, geologic processes, and non-native invasive plants and animals are currently monitored (Table 1.13). The existence of these long term data sets will be considered as part of the indicator selection and prioritization process. Many of the existing monitoring protocols for these indicators require review and will need to be integrated into a larger, long-term monitoring program. Monitoring programs are described further in Appendix

8. Participating agencies and existing and potential monitoring partnerships are summarized in Appendix 9. Much of the potential for monitoring partnerships exists because other agencies and institutions are planning or conducting their own monitoring programs on lands adjacent to the parks. Known monitoring programs on lands adjacent to the SFAN parks are also highlighted in Appendix 9.

Table 1.13. Summary of current and historical monitoring programs within the SFAN parks. Numbers in the columns for each park represent the number of years monitoring has been conducted in that park for the corresponding program. Participating agencies and partners are listed for each program.

Monitoring Program	**EUON**	**FOPO**	**GOGA**	**JOMU**	**MUWO**	**PORE**	**PINN**	**PRES**	**Participating Agencies and Partners****
ABIOTIC									
Air quality						20+	14		NPS, State
Air quality--visibility							H*		NPS
Cave conditions							6		NPS
Erosion monitoring				5			4		NPS
Fire history						30	24		NPS
Hydrologic monitoring			7-50			7			NPS, USGS
Night sky monitoring							3		NPS
Prescribed burn plots						14	14		NPS
Restoration site geomorphology							6		NPS
Scour chains (vertical)							H		NPS
Seismic activity	35	35	35	35	35	35	35	35	USGS
Shoreline change (LIDAR)			4			7			USGS
Stream geomorphology				2		7	6		NPS
Visitor trail use							5		NPS
Water quality			4	2	4	4	6		NPS, State
Watershed assessment			5	2	5	5			NPS, USGS
Weather	1			1		38	67		NPS, NOAA
BIOTIC									
Acorn production							H		NPS
Amphibians			10			10	4		USGS/NPS
Bank Swallows			9						NPS
Beached bird surveys			9			26			NPS, NOAA,PRBO
Benthic invertebrates/intertidal zone			8			8			NPS
Butterflies (listed species)			10			10			NPS, Stanford

Monitoring Program	EUON	FOPO	GOGA	JOMU	MUWO	PORE	PINN	PRES	Participating Agencies and Partners**
Cattle grazing (RDMs)			15			15			NPS
Coho salmon and steelhead trout			10			7			NPS
Cooper's hawk							H		NPS
Eel grass beds			10			10			NPS, CDFG
Harbor seals			26			27			PRBO/NPS
Herons, egrets			10			7			NPS, Audubon
Juvenile rockfish			20			20			NMFS
Land birds			9			35			NPS, PRBO
Mountain Beaver			7			7			USGS
Nearshore productivity (CODAR)						3			UCD
Non-native plants (selected species)	1		10+	1		8	6		NPS
Northern elephant seals						22			PRBO/NPS
Northern spotted owls			9		9	9			NPS, PRBO
Oak mortality/reproduction				1			4		NPS
Pacific herring			25			25			CDFG
Prairie falcon							16		NPS
Raptors			15						GGNPA
Rare plants			10+			10+			CNPS, NPS
Red-legged frog						10	4		NPS, USGS
Seabirds (several species)			10			20			FWS, PRBO, NPS
Shorebirds/water birds			16			16			NPS, Audubon, PRBO
Small bird distribution/abundance							20		NPS
Small mammals						5	20		NPS, USGS
Steller and California sea lions						20			NPS
Stranded marine mammals			10+			20+			NMFS,MMC,MVZ
Terrestrial vertebrates			5			5			NPS, USGS
Townsend's big-eared bats						10+	6		NPS, USGS
Turkeys/Peafowl						4			NPS
Ungulates—elk						24			NPS, CDFG
Ungulates—native & exotic deer			3			3			NPS, CDFG
Vegetation mapping		7	7		7	7	19	7	NPS
Western snowy plover			8			30			PRBO, NPS
Wildlife diseases (several)						5			NPS, UCD

*H=historical monitoring projects.

**Audubon=National Audubon Society; CNPS=California Native Plant Society; CDFG=California Department of Fish and Game; FWS=U.S. Fish and Wildlife Service; GGNPA=Golden Gate National Park Association; MMC=Marine Mammal Center; MVZ=Museum of Vertebrate Zoology; NMFS=US National Marine Fisheries Service; NOAA=US National Oceanographic and Atmospheric Administration; NPS=National Park Service; PRBO=Point Reyes Bird Observatory; Stanford=Stanford University; State=California state agencies; UCD=University of California at Davis; USGS=US Geological Survey.

1.4.2 Summary and Analysis of Water Quality Monitoring Data

Key water issues in the network include impacts from agricultural operations on water quality and aquatic habitat, marine and estuarine protection and restoration, and restoration of aquatic and riparian habitat. Many of the park units in the SFAN have completed some level of land use assessment and water quality monitoring. The context of monitoring has been both regulatory and status/trends related (as noted in Table 1.14). Through outside agency involvement and park initiative, recreational monitoring programs are in place for beaches at PORE and GOGA. NPS Director's Order # 83 is followed for beach water quality monitoring. Regional Water Quality Control Board requirements and American Public Health Association (APHA) Standard Methods protocols are followed for all water quality monitoring. The USGS protocol is followed for all aspects of a pilot project to determine sediment load using the Turbidity Threshold Sampling Technique.

Although data quality assurance indices have not been formerly developed for the water quality data, standard operating procedures were followed and metadata are available. Much of the data has been entered into established databases, but a significant amount of data also exists in spreadsheet or raw form. Portions of the existing water quality monitoring data for PORE and GOGA have been analyzed and synthesized into reports (Appendix 6). A significant amount of data has not been formally analyzed; however, data from PINN, GOGA, and PORE are currently being analyzed through a contract with UC Berkeley. Additional analysis will be conducted as the initial stage in the Long-Term Water Quality Monitoring Plan. Parameters monitored include flow, temperature, pH, dissolved oxygen, salinity, specific conductance, nitrates, nitrites, ammonia, orthophosphates, indicator bacteria (fecal/total coliform, *E. coli*, and enterococci), metals, and total suspended solids. Not all of these parameters have been monitored at all parks or all stations within each park.

Table 1.14. Water resources monitoring summary.

Indicator	Type of Monitoring	Parks Monitoring*
Water Quality	Status & trends / Regulatory	GOGA, PINN, PORE
Water Clarity	Status & trends / Regulatory	GOGA, PORE
Nutrients	Status & trends / Regulatory	GOGA, PORE
Metals	Status & trends / Regulatory	GOGA
Pathogenic Bacteria	Status & trends / Regulatory	GOGA, PORE
Benthic Macroinvertebrates	Status & trends	GOGA, PINN, PORE
Oil/Hydrocarbons	Status & trends	
HAB	Status & trends	
Surface Water Dynamics	Status & trends	GOGA, PINN, PORE
Groundwater Dynamics	Status & trends	
Oceanographic Physical Parameters	Status & trends	
Flooding	Status & trends	
Waves	Status & trends	
Drought	Status & trends	

* Includes past or present monitoring

Monitoring efforts within GOGA (including PRES and MUWO) have been on-going (though not continuous) since the late 1980's. Sites have been located in several different watersheds and monitoring has focused primarily on evaluating impacts associated with stable operations. PINN has conducted baseline water quality monitoring in Chalone Creek (at sites throughout the park) since 1997. PORE monitoring (since 1999) has focused on evaluating the impacts of agricultural operations (dairy cattle, beef cattle, and equestrian operations). Water quality monitoring of Tomales Bay and Drakes Estero has been ongoing since the early 1990s in conjunction with State Department of Health Services shellfish production requirements. In addition, the USGS has recently completed the last of a three-year NAQWA level water quality monitoring of four watersheds (within GOGA and PORE) supporting coho salmon and steelhead trout.

Pathogenic bacteria are a primary threat to water quality in SFAN. Indicator bacteria have consistently exceeded water quality criteria at many inland surface water monitoring sites at PORE and GOGA. This pollutant is also suspected to be a threat at JOMU and possibly PINN. Seasonal variability in bacteria concentrations has been detected and correlates with rainfall and runoff conditions. Efforts to improve water quality are on-going. A consultant for PORE has performed "Dairy Waste Management System Evaluations" for all of the ranches in the park. Best Management Practices have been implemented and research by local universities is proposed for the Tomales Bay watershed.

Chapter 2 Conceptual Models

2.1 Ecological Conceptual Models

An ecological conceptual model is a visual or narrative summary that describes the important components of an ecosystem and the interactions among them. Development of a conceptual model helps in understanding how the physical, chemical, and biological elements of a monitoring program interact, and promotes integration and communication among scientists and managers from different disciplines. Increased understanding and communication gained throughout this process may lead to the identification of potential indicators (Roman and Barrett 1999). Ecological conceptual models also aid in defining relevant spatial and temporal scales to provide an appropriate context for the ecosystem components and processes being considered.

Conceptual models are expressed in many different forms, including tables, matrices, box and arrow diagrams, graphics, descriptive text, and combinations of these forms (Jenkins et al. 2002). Typically, audiences are most receptive to visual models, but the specific model form used will depend on the modeler's objectives (Noss 1990). Diagrams depict simplified relationships and system components, whereas text and tables provide details that may be lost in the simplified pictorial representations.

Unfortunately, no one model form describes an entire system adequately. Model generality is needed to characterize broad-scale influences and relationships among park resources, while model specificity is required to identify detailed relationships and components in the system that can be effectively monitored and subsequently managed. Consequently, both broad-scale models and specific models are needed to adequately represent ecological systems having the spatial scale of national parks. Because of this need to integrate both broad- and fine-scale components and processess into an ecological conceptual model, the SFAN developed a hierarchical model with successive layers representing increasing model specificity.

Conceptual model development is an iterative and interactive process. Models are expected to change as a network's monitoring program develops and as ecological linkages are better understood. Details will be added to SFAN models, especially indicator-specific models, as Vital Signs are selected and prioritized, and as monitoring programs are implemented and assessed for the network.

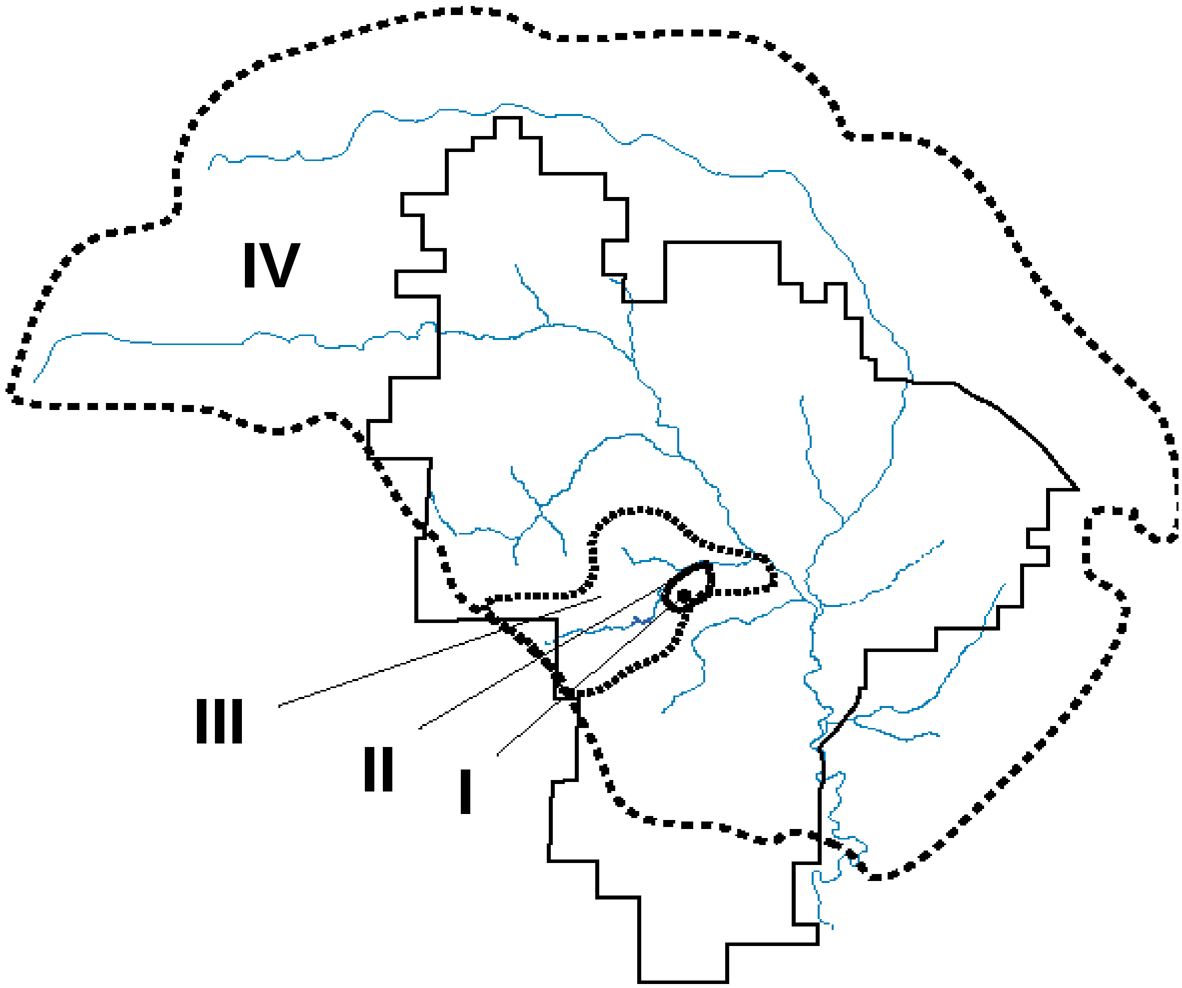
2.2 Organizational Structure of SFAN Conceptual Models

The SFAN model is hierarchical, with each layer of the model becoming increasingly more specific. Layers of the SFAN model include:

1. A generalized conceptual model,
2. Three ecosystem models representing the dominant ecosystem types in the network--marine, aquatic/wetland, and terrestrial ecosystems, and
3. A matrix representing the relationship between drivers and stressors and general indicator categories grouping similar ecosystem components and processes.

Coarse indicator categories were used at this level of the model to create indicators that were more comparable for ranking purposes. As the SFAN Vital Signs Monitoring program develops, more refined diagrams will be created depicting understood and hypothesized relationships between drivers/stressors and specific indicators selected for monitoring purposes. Based on these fine-scale layers of the model, specific indicators can be ranked from a subset of high-priority, general indicator categories. Coarse and specific indicators can be linked back to management issues and relevant monitoring questions outlined in Section 1.3.2.

Nested spatial scales ranging from 20-meter habitat patches to 100 kilometer coastal zones for marine ecosystems emphasize the importance of selecting indicators that may be used to evaluate ecosystem integrity at various levels of ecological organization (Figure 2.1; see also Section 1.3.1.1). Temporal scale also varies in relation to the indicator, but indicators should be evaluated within 20-year increments or less.



Scale	Name	Size	Scale Synonyms	Examples
I	Habitat	20 m	Patch	phoebe nest territory
II	Community	200 m	Vegetation type	chamise chaparral unit
III	Sub Watershed	5 km	Landform	Bear Gulch drainage
IV	Watershed	20 km	Park Boundary, aquifer	Chalone Creek
V	San Benito Co	50 km	Mountain range	SCoRI floristic subregion
VI	Cen Coast Ranges	100 km	Region, ecoregion	Salinas river, Salinian Block
VII	Coast Ranges	500 km	Csa climate type	Mediterranean- mild winter
VIII	California	1000 km	Floristic provnce	California
IX	Western Province	2000 km	Pacific cordilliara	subduction geology controlled
X	Global	20000 km	Planetary	Earth

Figure 2.1. Nested spatial scale example relevant to the SFAN conceptual model, as depicted for PINN.

2.3 Conceptual Model Definitions

Terms integrated into the SFAN conceptual models are defined in the report Glossary to clarify their use in the model layers.

2.4 Descriptions of Drivers

Ecosystem drivers are major external driving forces such as climate, fire cycles, biological processes, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. Ecosystem drivers listed below are the product of network Vital Signs scoping workshops and represent the dominant external forces for the SFAN. Natural disturbance regimes are considered as part of each driver category.

Solar/Lunar Cycles

Solar and lunar cycles include the rotation of Earth on its axis causing daily periodicity (i.e. night and day), the revolution of the moon around Earth creating variation in tides and lunar phases (lunar cycles), and the revolution of Earth around the sun causing seasonal changes. Over the course of time, plants, animals, and entire communities have evolved reproductive, growth, and behavioral characteristics in response to these cycles. For example, kangaroo rats avoid the heat of the desert sun through nocturnal habits, which are synchronized with lunar phases. Moonlight has been shown to affect habitat use of small rodents. On full moon nights, some rodents are less likely to use open habitats for foraging (Jensen and Honess 1995). Moonlight also affects the nocturnal activities of seabirds during the nesting season (Hyrenbach and Dotson 2001). Organisms living in intertidal communities have adapted various physiologic traits and behavioral responses to contend with tidal fluctuations. Deciduous plants lose their leaves to reduce transpiration rates during winter months. Both solar and lunar cycles influence ecosystem dynamics at varied spatial and temporal scales.

Climatic Variability

Climate is associated with the broad-scale, long-term patterns of weather which drive the distribution and abundance of biota in a given region or biome. For the SFAN, the temperature and precipitation patterns governing the flora and fauna are characterized by a moderate Mediterranean climate which offers long growing seasons and supports diverse plant and animal communities (Bailey 1995). On a geologic time scale, climate does change and with it the organisms representative of a given biome. In contrast, weather is so variable from year to year that detection of significant change is difficult and requires long-term monitoring. Changes in weather events, growing season changes, and other aspects of natural disturbance regimes may alter natural communities and facilitate general change in species/habitat distributions (Spellerberg 1991). For instance, recurring Pacific Decadal Oscillation or El Niño-Southern Oscillation events affect temperature and precipitation patterns and produce significant changes in abiotic and biotic ecosystem components (Thurman 1988). These changes are within the natural range of variation, although human activities may be altering the frequency and intensity of these events (NAST 2001). Potential impacts to sensitive ecosystems, endemic species, and threatened or endangered species are of particular concern. A long-term meteorological monitoring program is essential to evaluate how meteorological agents of change within the natural range of variation influence the functioning of ecosystems.

Geologic Processes

Geologic processes include tectonic, volcanic, surficial, and geomorphic processes. Volcanic activity, the force partly responsible for the Pinnacles formations, brings minerals and rock to the Earth's surface from its interior. Earthquakes, which can play a part in the physical breakdown and burial of rock surfaces, can expose new rock surfaces and minerals through uplift and rock shearing. Tectonic activity along the San Andreas Fault is a significant force shaping SFAN ecosystems and is responsible for thrusting the volcanic material at Pinnacles upward and for the formation of Tomales Bay and Bolinas Lagoon of GOGA and PORE. Newly exposed features provide opportunities for colonization by both flora and fauna, sometimes on distinctive formations or minerals of regionally unique composition. Mass movement works to breakdown geologic materials on a range of spatial scales from erosion of stream bank material to large landslides. Mass movement of rock, debris and sediment may take place suddenly (i.e. debris avalanches, lahars, rock falls and slides, or debris flows) or more slowly (i.e. slumping, creep, or slip). Other natural forces such as wind, water, and fire can affect the rate and magnitude of mass movement. In concert, geologic processes create unique formations such as caves, spires, and abyssal trenches, expose minerals such as serpentinite that influence biological activity, and alter surficial and geomorphic features to create a heterogeneous landscape (i.e. topographic and bathymetric variation; Bloom 1998). These processes set and reset the stage for colonization and establishment by diverse biological communities.

Nutrient Cycles

Nutrient cycles link the biotic and abiotic components of an ecosystem through a constant change of materials, especially carbon, nitrogen, and phosphorus. The carbon cycle, for example, is an essential ecosystem process, in which insects, vertebrates, saprophytes, pathogens, and fire all play important roles. Nutrient cycling is considered an integrating variable, since the cycles occur across scales and involve the atmosphere, biosphere, lithosphere, and hydrosphere. While nutrients may be transported great distances in water or air, the key transformations that make these elements available to plants (and so to animals) are driven by soil microbes, as are the reactions that release the elements back to air or water, to repeat the cycle. Ecosystems on stable trajectories have biological interactions that tend to conserve key nutrients (Chapin et al. 2002). Significant loss or gain of elements is a good indicator of change in the system such as acidification or large accumulations or losses of biomass.

Oceanography (Physical Parameters)

Oceanography is identified as the branch of science dealing with physical and biological aspects of the oceans. These physical and/biological aspects (including waves, oceanic circulation, tides, and the interactions with biotic elements) function together both as a driver and an indicator. Tectonic driven sea waves, for example, inundate coastal areas (subtidal, intertidal, and supratidal) causing changes in species distribution and abundance. Daily, seasonal, and annual variation in tides and changes in ocean circulation (seasonal and annual) stress coastal areas. Examples of larger scale changes in ocean circulation include Pacific Decadal Oscillation, El Niño-Southern Oscillation, and North Pacific Oscillation and produce significant changes in abiotic and biotic components of the marine ecosystem (Thurman 1988). These physical and/biological aspects of the oceans can also serve as excellent indicators of ecosystem change. Examples of standard indicators measured by NOAA include sea surface temperature, sea surface salinity, seasonal changes in sea level, the frequency of El Niño-Southern Oscillations, and the distribution of nearshore currents.

Coastal Processes

Erosion and accretion of shoreline deposits and relative shoreline position are important factors in determining the ecosystem health and appropriate land uses in coastal areas. Changes in relative sea level may alter the position and morphology of coastlines, causing coastal flooding, water-logging of soils, and a gain or loss of land (Carter 1988). Changes in the shoreline position may also create or destroy coastal wetlands and salt marshes, inundate coastal settlements affecting coastal structures and communities, and induce saltwater intrusion into aquifers, leading to groundwater salinization. Subtle changes in sediment supply and physical processes can shift the balance between shoreline stability and accretion or shoreline erosion (Carter and Woodroffe 1994). These shoreline changes may have significant implications for coastal ecosystems, human settlements, and land uses. Relative sea level variations may be natural responses to climate change, movements of the seafloor, and other earth processes.

Hydrologic Processes

The physical, hydraulic, and chemical properties of streams and rivers determine their suitability as habitat for aquatic plants and wildlife. Conditions appropriate for spawning, for example, are defined by water depth, water velocity, size of substrate, and availability of cover provided by overhanging vegetation, undercut banks, submerged logs and rocks, among other stream characteristics (Regart 1991). Similarly, flow frequency and duration, water depth and velocity, seasonality, and stream morphology dictate the composition and abundance of aquatic macroinvertebrates, macrophytes, and other aquatic organisms at any given time. Hydrologic disturbance, particularly in the form of flooding, plays a key role in aquatic ecosystems of the SFAN. Flooding events alter succession, shift species composition, flush nutrients and other compounds into and out of the system (influencing terrestrial ecosystems, too), and reshape channel morphology (Gordon et al. 1992). Channel shape and flow patterns are therefore dynamic. Changes in sediment yield reflect changes in basin conditions, including climate, soils, erosion rates, vegetation, and topography. Fluctuations in sediment discharge affect many ecosystem processes and components because nutrients are transported with the sediment load. Consequently, water chemistry fluctuates naturally as and when environmental conditions change, thereby affecting aquatic communities downstream.

Fire Cycles

Fire is a significant driver for many ecosystems especially those characteristic of Mediterranean climates. Chaparral communities and Bishop pine forests are especially responsive to fire. Fire changes species relationships and/or community composition by consuming much of the living vegetation, litter, and dead material, releasing nutrients bound in organic materials to the environment and killing or reducing the density of some species (Barbour et al. 1980). Because of its prevalence as a natural disturbance, plant communities in the San Francisco Bay Area have adapted to fire over evolutionary time. Some species such as Bishop pine are fire dependent, relying on fire to open and release seeds from resinous cones which benefit from improved growing conditions such as available sunlight, a seedbed of bare mineral soil, and nutrients released from organic matter cleared by the fire. Other species including Coast live oaks are fire tolerant, surviving and regenerating vegetatively following fire disturbance. Lightning, the most significant source of natural fires, is rare in the SFAN, but sparks from falling rocks, volcanic activity, and spontaneous combustion of plant materials and organic matter can also ignite fires (Barbour et al. 1980).

Biological Processes

An ecosystem consists of plants, animals, and microorganisms interacting with each other (the community) and with their physical (e.g., soil conditions and disturbance regimes) and climatic environment in a given area. Communities change naturally over time in response to changes in environmental variables, disturbance regimes, and species interactions. Within an ecosystem, ecosystem integrity results from plant and animal interactions such as herbivory, competition, biological invasions, predation, allelopathy, disease, and mutualism. These relationships allow for the flow of energy and the cycling of nutrients and other materials throughout the system (Chapin et al. 1997). Plants and animals interact in ways that affect ecosystem integrity both positively and negatively (e.g., deer browsing, fern shading, nest parasitism, mycorrhizal associations). The interactions among species in an ecosystem may alter successional/evolutionary pathways, leading to changes in the structure, composition, and function of ecosystems (Chapin et al. 1997). For example, herbivory may lead to reductions in relative abundance or extirpation of one or more plant species, which may, in turn, reduce the abundance of certain habitat types for other organisms. These changes are part of natural fluctuations that ecosystems undergo and may lead to alternate developmental pathways for the ecosystem.

2.5 Descriptions of Stressors

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems.

Climate Change

The greenhouse effect, which warms the Earth's atmosphere, results from the interaction of solar radiation with accumulated greenhouse gases (e.g., carbon dioxide, methane, chloroflorocarbons, and water vapor) in the atmosphere. This warming effect has been enhanced over the past century by increased contributions of these gases, particularly carbon dioxide, from anthropogenic sources (NAST 2001). Potential consequences of this enhancement are rising seasonal temperatures, altered dates for first and last frost, increased drought occurrences, increased storm/flooding severity and frequency, increased biological invasions, and decreased predictability of weather patterns, all of which directly affect ecosystems. These changes may also alter natural ecosystem disturbance regimes (including fire), and can facilitate exotic species invasions. The San Francisco Bay Area is predicted to have increased rainfall, and more intense and more frequent El Niño-Southern Oscillation events. Climate change models predict that sea levels may rise from 5-37 inches over the next 100 years (NAST 2001). Climate change may impact shoreline erosion, saltwater intrusion in groundwater supplies, and inundation of wetlands and estuaries. These are vital resource management concerns along the 120 miles of network shorelines. Increased and more intense precipitation would also increase erosion and flood events at all of the parks, which are characterized as erosible soils. Sea temperature is also predicted to continue to rise. Central California waters have already increased in temperature over the past 30 years, resulting in changes in the distribution of many marine species of invertebrates and fishes (Croll et al. 2000). Temperature rise may also be more conducive to the invasion of non-native species, both aquatic and terrestrial, and range extensions of native species leading to hybridization and increased competition. Temperature rise also may affect biogeochemical cycles (NAST 2001).

Air Quality Degradation

Air quality degradation encompasses several different sources of stress including acid deposition, tropospheric ozone, increased carbon dioxide concentrations, an increase in the concentration and/or type of toxins and heavy metals, visibility/haze, radioisotopes, and nitrification (EPA 1999). Any of these factors may interact with the others amplifying their effects on ecosystems. Of concern are impacts to plant communities, water quality, non-native species invasions, nutrient cycling, and unique habitats/species. For instance, acid deposition can result in the leaching of nitrogen and calcium from ecosystems thereby affecting productivity, soil chemistry, water quality, biodiversity, and resistance/tolerance of biota to other stresses (Adriano and Havas 1990). Increased deposition of heavy metals, especially mercury, may result in bioaccumulation and bioconcentration with potential toxic effects to primary, secondary, and higher consumers. Direct effects of elevated levels of carbon dioxide and tropospheric ozone on native and exotic biota, include adverse changes in their competitive ability, distribution, and survival, reducing biodiversity. Particulate matter reduces visibility, particularly with increased humidity, and can combine with tropospheric ozone to produce photochemical smog. Photochemical smog has been linked to respiratory ailments in fauna and reduced vigor in floral species (Chappelka et al. 1996, 1999).

Water Quality Degradation

Water resources are of national concern as water bodies increasingly become diverted, polluted, and used by conflicting interests. In the SFAN, water quality is a very high profile issue because of the network’s proximity to a large urban area. Water quality concerns include external sources of pollution, inappropriate visitor use, atmospheric deposition (stream acidification), water pollution effects on park ecosystems and water use, and loss of aquatic biota (Karr and Dudley 1981). Industrial, agricultural and recreational pollution threatens the water resources of the parks. The Norwalk virus, for example, contaminated shellfish and sickened over 100 people in Tomales Bay in 1998 (Ketcham 2001). Where streams originate outside park boundaries, water quality changes, particularly nitrogen and phosphorus content, can be indicative of agricultural fertilizer use or signal a reduction in productivity and/or vegetative cover upstream (Fong and Canevaro 1998). Organic chemical content may indicate land use changes upstream, especially mining or industrial activity. These organics affect freshwater mussels and other aquatic organisms directly and are also indicative of overall watershed problems affecting riparian and terrestrial biota (Gordon et al. 1992). Inorganic chemicals such as pesticides and industrial waste also negatively affect aquatic biota. Increased acidity in aquatic systems can raise concentrations of dissolved aluminum, which is toxic to native aquatic and terrestrial biota (Adriano and Havas 1990).

Water Quantity Alteration

Streams, lakes, wetlands, and groundwater resources can be altered by impoundments, water withdrawal, expansion of impermeable surfaces in watersheds, climate change, loss of riparian buffers, and changes in runoff characteristics under various vegetation conditions. Water transport and diversion are also significant stressors manifested in sediment deposition/erosion, accretive/avulsive meandering, flow regimes (bankfull/dominant discharge/peak flow) based on channel forming flow, and long-shore sediment transport (Brooks 2003). These changes can affect stream high and low flows in response to weather events, aquatic and terrestrial species, and recreation and aesthetics. Impermeable surfaces and other products of urbanization can increase downstream flow extremes, indicating habitat loss and fragmentation. Water level fluctuations in ponds, wetlands, and stream discharge are directly linked to groundwater levels and hydrology which influence vegetation dynamics. An understanding of water table levels is required for predicting the effects of natural and human-induced hydrological changes (e.g., sea level rise, drought conditions, municipal groundwater withdrawal) and the fate of contaminants (Fetter 2000). Groundwater may be the significant water source for certain riparian systems, wetlands, and municipal water supplies (sole-source aquifers). Altered water quantity can also affect water quality, flooding events, and water temperature profiles. Both terrestrial and aquatic ecosystems are affected by these alterations which, in turn, can lead to erosion or sedimentation, habitat degradation, non-native species invasions, riparian and wetland habitat loss, and decreased biodiversity (Gordon et al. 1992).

Human Population Increase

With a population of 7 million people, the metropolitan centers of San Francisco, Oakland, and San Jose are forecast to have a population of 8 million by 2020 (Association of Bay Area Governments 2000). Preserving biologically and geologically diverse habitats and their associated species, as well as providing opportunities for recreation, education and aesthetic enjoyment to a large urban population is a difficult balancing act. Population increase inevitably results in land use change. For the parks, this includes pressures from adjacent lands, as well as activities inside parks, such as trampling of sensitive plant communities, compaction of soils, creation of social trails, and excessive impact on caves, wetlands, and other sensitive ecosystems. Increasing human populations lead to sources of light pollution, altering wildlife behavior and affecting feeding, migratory, and reproductive cycles (Advise and Crawford 1981). Increasing sound levels from outside the parks and inside the parks can have similar effects on wildlife Bondelo 1976, Brown 1990). Excessive noise levels also negatively affect visitor experiences. Human encroachment on park boundaries can also disrupt scenic overlooks that extend beyond park boundaries. Increasing numbers of people often increase the number of feral animals in the region, putting pressure on park wildlife and vegetation (NPCA 1977). Increasing vehicle traffic volume in and around the parks also leads to increased road mortality and the introduction of non-native species.

Land Use Change/Development

Land use change and development pressures manifest themselves in different forms including industrial and residential development, coastal development, aquaculture, storm water management, intensive grazing and agriculture, hazardous material spills, increased habitat loss and fragmentation, and increased visitor pressure on park resources (NAS 2000). Habitat fragmentation is one of the most significant products of land use change and encompasses many of the other issues threatening park lands. Habitat fragmentation is a function of edge-to-area ratio and habitat connectivity. Habitat fragmentation has cascading effects on habitat quality, quantity and distribution of habitat, predator and prey densities and distribution, nutrient levels, pollutant loads, and disease and pathogen incidence and distribution (Wilcove et al. 1986). Habitat fragmentation can also create barriers preventing the normal distribution or dispersal of species, isolating them on islands of parklands. Parks may become sources or sinks for populations, and consequently, increase complexity of species management. Development can include construction of roads, buildings, and parking lots, wetland conversion, or conversion of adjacent agricultural land from grazing to vineyards. Certain species require open space for all or part of their habitat requirements while other species require vegetation cover for their habitat needs. Changes in the ratio of open space to cover are good indications of shifts in habitat availability for the relevant species and communities (NAS 2000). Land use changes and development can have significant impacts on habitat availability. Both the type and quantity of different land uses should be identified and monitored in and around the park.

Resource Extraction

Resource extraction results from dredging, sand mining, timber harvesting, harvesting of animals and herbaceous plants, recreational and commercial fishing, aquaculture and withdrawal of limited water resources. Because of these activities, dredge soil disposal, contamination, erosion, siltation, species loss, alteration of habitat, reduced water quality and quantity, and impacts from construction and access become significant management issues. In the SFAN, these issues concern all ecosystems, marine, terrestrial, and freshwater. Mineral and soil extraction can increase sedimentation of downstream water bodies or increase pollutant concentrations associated with extractive by-products. Extracting water, river rock, sand and gravel can alter habitat by changing flow volume and patterns, reducing bank stability and changing sediment deposition patterns (Brooks 2003). Water table changes may also occur as a result of mining and well drilling which can affect ground water-dependent habitats (Fetter 2000). Timber harvesting and poaching are problems for park biota within and adjacent to parks. Oil spills and hazardous chemical spills are of concern as well, since San Francisco Bay is a major shipping port.

Soil Alteration

Soils are important to ecosystem integrity because they provide the primary media and components for most nutrient cycles while, in some cases, dictating the structure and functions associated with ecosystems on a given soil type. Soils can be altered by development activities, atmospheric deposition, climate change, altered precipitation patterns, water quality and quantity alteration, resource extraction, and changes in disturbance regimes. Erosion or sedimentation, soil compaction, changes in soil carbon and organic matter content, loss of soil biotic diversity, and altered soil chemistry can result from soil stressors. Erosion and sedimentation are directly indicative of soil disturbance and provide a good indicator of the rate or extent of land use change (NAS 2000). Although sediments are a natural part of most aquatic ecosystems, human activities have dramatically increased sediment inputs to lakes, streams and wetlands (Brooks 2003). Soil compaction can limit water infiltration, percolation, and storage, affect plant growth and alter nutrient cycling. Changes in soil carbon affect community productivity (Barbour et al. 1980). Soil organisms, which are sensitive to changes in soil structure and chemistry, are essential to the formation and maintenance of soils as well as being key components in nutrient cycles (Crossley and Coleman 2003). Significant alterations in soil biota will inevitably affect nutrient cycling and ecosystem functions.

Nutrient Enrichment

Nutrient enrichment (excess nitrogen and phosphorus concentrations) can affect marine, terrestrial, and aquatic ecosystems. Typically, nutrient enrichment results from excessive erosion, agricultural and commercial fertilizers, and runoff. Elevated concentrations of nitrogen and phosphorus cause dramatic shifts in vegetation and macroinvertebrate communities, paving the way for non-native species invasions and reduced biodiversity. As an example, nitrogen-loading in shallow estuarine embayments can lead to shifts in the dominant primary producers (e.g., macroalgae may replace eelgrass), which can lead to declines in dissolved oxygen, altered benthic community structure, altered fish and decapods communities, and higher trophic responses (Bricker 1999).

Park Development and Operations

Increasing demographic pressures in the SFAN parks have included increased visitation. The rise in visitation puts greater demand on park resources and often requires changes in the amount of infrastructure and operations. Park roads may need to be resurfaced or extended. Parking lots may need to be expanded. Visitor and interpretive centers, campgrounds, and other facilities may need to be built or upgraded. Interpretive media may need to be maintained and sometimes relocated. On a broader scale, management activities such as installation of coastal barriers, fire suppression, grazing, invasive species control, removal of vegetation, and reclamation of nearshore areas can alter ecosystem structure and function. All of these activities impact the parks' natural resources and influence visitor use.

Recreational Use

Demographic changes can dramatically increase park visitation and recreational use, sometimes to unsustainable levels. This visitation pressure extends to trails and backcountry resources. The current broad variety of uses within the parks exacts a toll on the natural resources. Hang gliders, dogs, mountain bikes, horses, kayaking, environmental education groups and hikers combine to put continued strain on wildlife, vegetation, water resources, and soils. The millions of visitors that frequent the SFAN parks each year have adverse impacts to sensitive plants and wildlife. This high level of visitor use creates demands for continued park development, or upgrade of existing development, particularly of trails, which fragment wildlife habitat, bring people into sensitive areas, and contribute to off-trail use in these sensitive areas (National Park Service 1997).

Fire Management

Fire can be a useful tool for managing ecosystems adapted to fire disturbance regimes limiting invasive species, and controlling fuel loads. Fire prevention, suppression, and prescription all carry management consequences with them leading to impacts on natural resources. While fire management may be necessary to maintain native ecosystems, our understanding of the appropriate fire intensity, frequency and duration required to do so is limited (Debano et al. 1998). Often, prescribed fires do not replicate natural fire and burnt areas become vectors of non-native plant invasions (Meyer and Shiffman 1999). Burnt areas also are susceptible to erosion. Conversely, infrequent burns can result in excessive fuel loads leading to intense fires that damage or destroy less-tolerant species.

Non-native Invasive Species/Disease

Non-native invasive species can reduce or eliminate native populations of flora and fauna, alter natural disturbance regimes, and change ecosystem functions. The sustainability of threatened and endangered species and the loss of more common species are of special concern. Non-native invasive plants, animals, diseases, and other pathogens also affect the structure and quality of habitat, alter species genetics and pollination dynamics, impact soil structure, biota, and chemistry, and can significantly affect watershed hydrology including evapotranspiration rates, stream flow, and erosion and sedimentation dynamics (Mack et al. 2000).

Disease is known to occur in all plant and wildlife populations and can significantly affect local demographics. However, the level of impact on a species population varies and is largely unknown. Bacteria, fungi, parasites, and viruses contribute to plant and wildlife diseases. Many disease agents and vectors are naturally found in the environment but their affect on species populations can be exacerbated by habitat fragmentation, overcrowding, genetic isolation. Other diseases are introduced into populations by alien species and foreign sources and can have dramatic impacts on local populations. Sudden oak death syndrome is a major concern in the SFAN (Rizzo and Garbelotto 2003).

Native Species Decline and Extirpation

Significant change in native species diversity is a key early warning of ecosystem distress (NAS 2000). But, significant decline or loss of native species populations can also be a stress to a community or ecosystem in its own right. Maintenance of viable populations of native species is a fundamental part of maintaining ecological integrity. Declining native populations, then, can lead to impaired ecosystem functions such as productivity, nutrient cycling, nutrient retention, energy transfer, habitat diversity and quality, terrestrial and aquatic linkages, and hydrologic function (Tilman 1999). In some cases, declining biodiversity may be linked to functional impairment. In other instances, a loss of functionality may be related to the decline or loss of a particular species. Loss of keystone species (e.g., starfish), umbrella species (e.g., elephant seals), or ecosystem engineers (e.g., mountain beaver) may be indicative of a shift in ecosystem type, resulting in cascading effects on other species (Lambeck 1997).

2.6 Generalized Conceptual Model

A generalized conceptual model was created to introduce the organizational structure of the SFAN model subcomponents (Figure 2.2). For conceptual purposes, ecosystems within the SFAN were divided into three types—marine, aquatic/wetland, and terrestrial—with each ecosystem type having associated subsystems or forms. Ecosystems were further divided into dominant resource realms—air resources (atmosphere), biotic resources (biosphere), water resources (hydrosphere), and earth resources (lithosphere)—to assist in organizing similar ecosystem processes and components. Key drivers and stressors are also represented in this model acting on the different ecosystems along pathways associated with each resource realm. Stressors can act on ecosystems through the different resource realms directly or they can affect drivers which, in turn, affect ecosystems via resource realm pathways. Note that socio-political forces influence anthropogenic stressors.

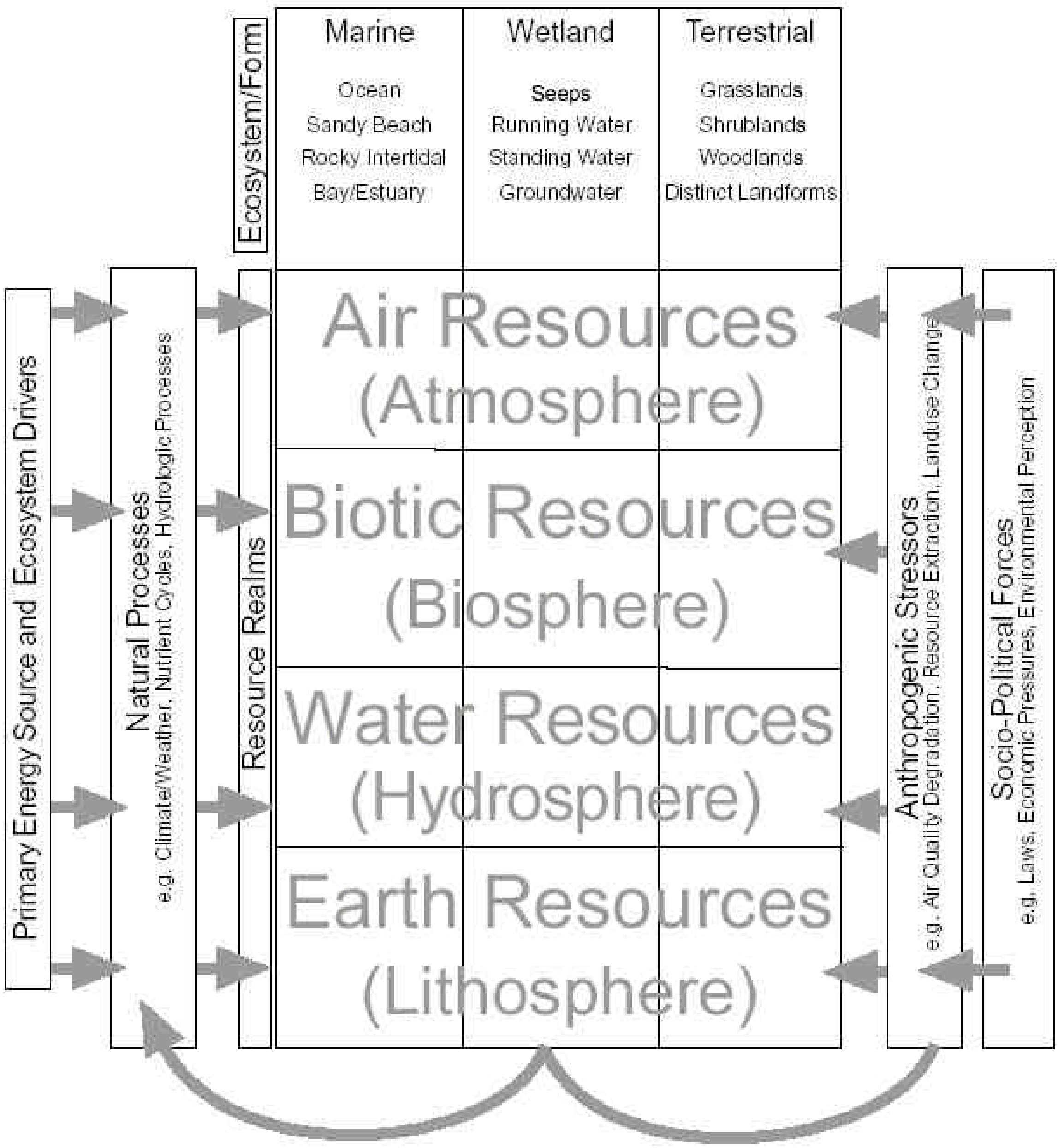


Figure 2.2. Generalized conceptual model for the San Francisco Bay Area Network.

2.7 Ecosystem Models

Individual conceptual models are presented for each ecosystem type: marine (Figure 2.3), aquatic/wetland (Figure 2.4), and terrestrial (Figure 2.5). Represented in each model are the dominant ecosystem drivers and stressors proposed for the SFAN. Natural and anthropogenic forces produce changes in ecosystem processes and components through their interactions with the forms associated with each ecosystem. Example effects resulting from these interactions are listed in the models. Examples of broad-scale indicators that may assist in monitoring the effects of ecosystem drivers and stressors on ecosystems also are depicted in the models. Note that not all possible effects or broad-scale indicators are depicted in the diagrams because of spatial restrictions. Indicators are organized by resource realm and ecosystem form. Also note that the biosphere realm is subdivided to reflect the need to monitor different levels of ecological organization. Terms used as part of the SFAN conceptual models are defined in the report Glossary.

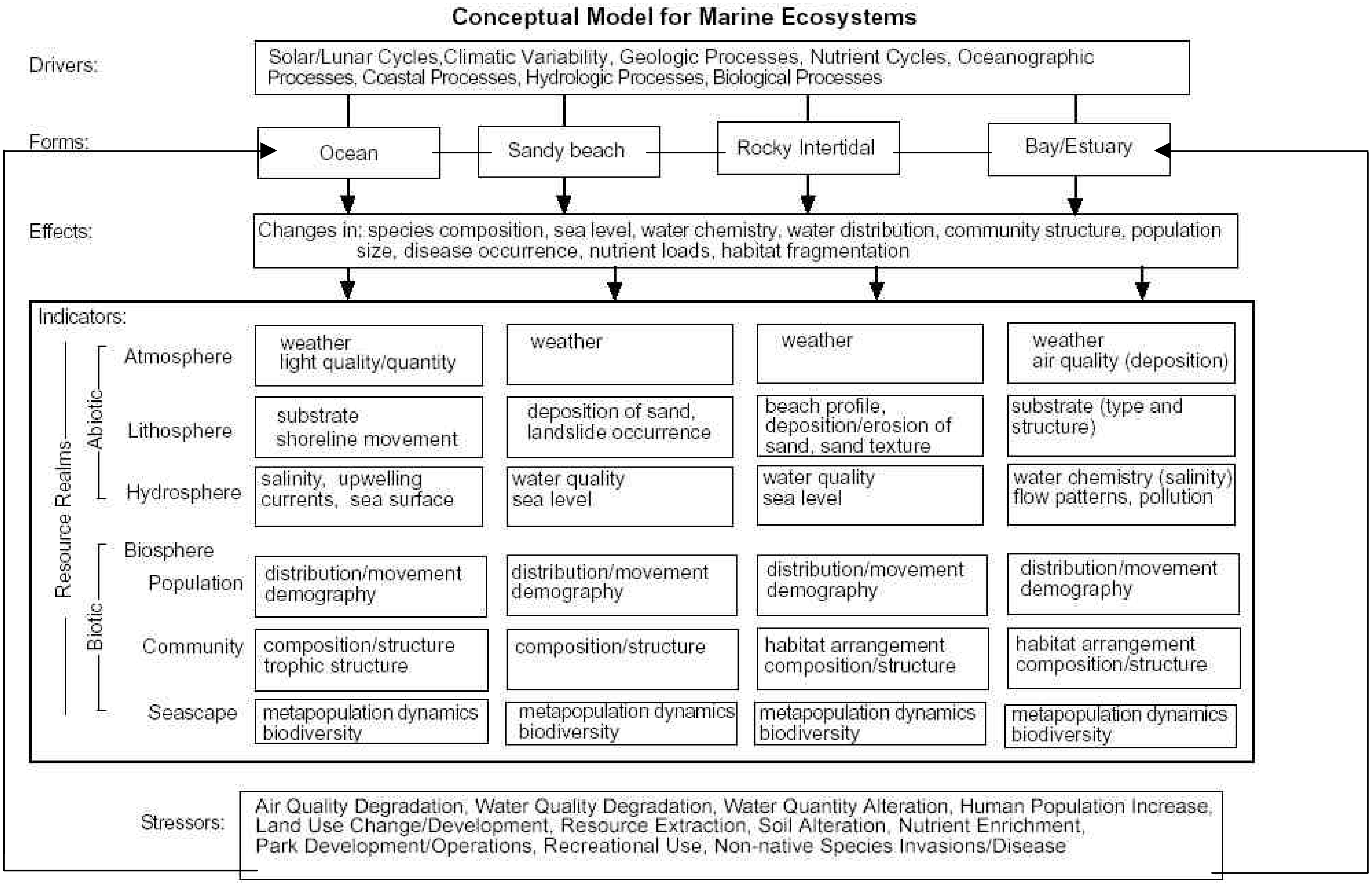


Figure 2.3. Marine ecosystems conceptual model.

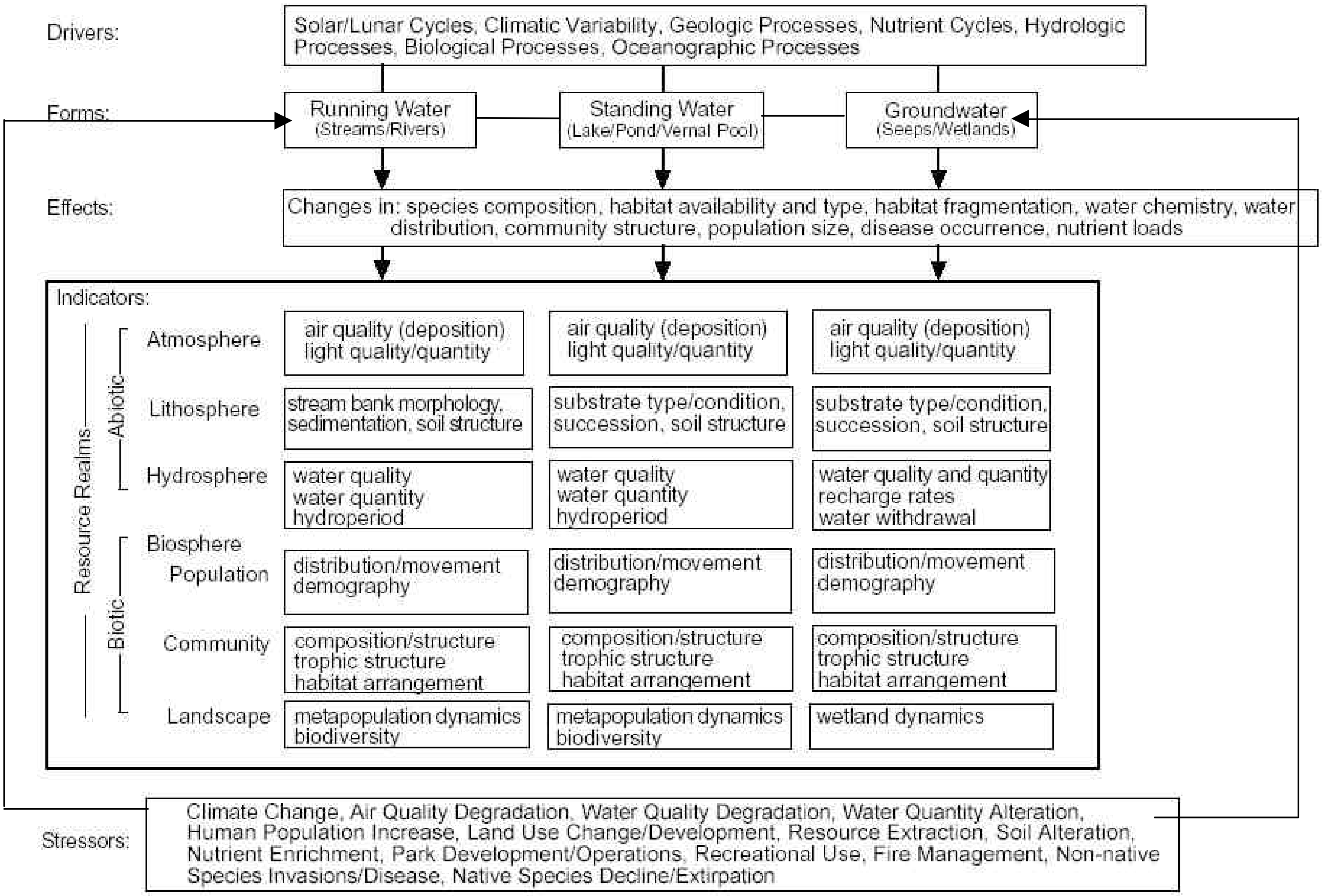


Figure 2.4. Aquatic/Wetland ecosystem conceptual model.

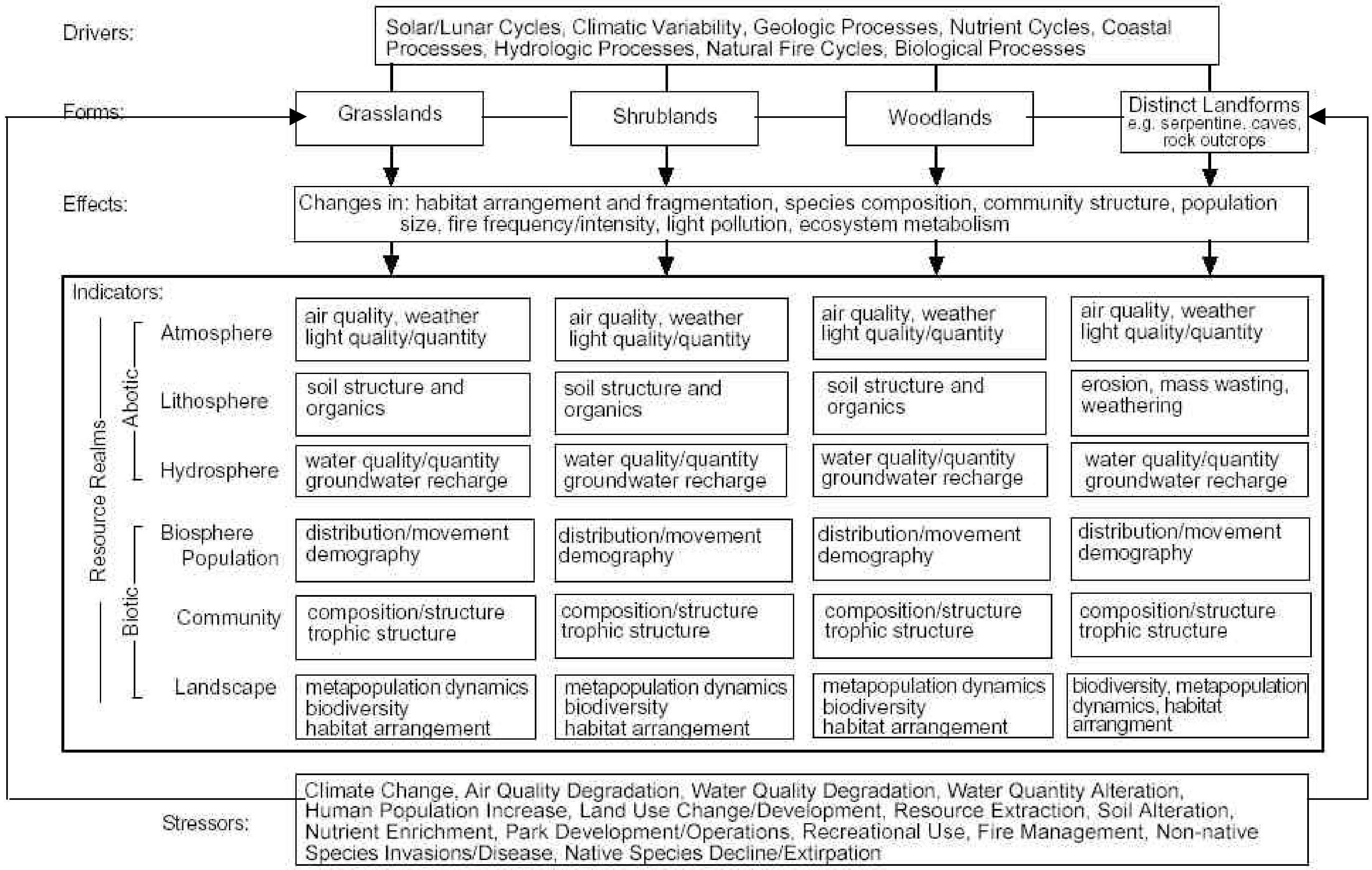


Figure 2.5. Terrestrial ecosystem conceptual model.

2.8 Driver, Stressor, and Indicator Matrix

Significant relationships between broad-scale (general) indicators, and drivers and stressors are summarized in matrix format (Tables 2.1 a-e). The matrix is continued on subsequent pages starting with the atmospheric realm on the initial page and ending with the lithosphere realm on the final page of the matrix. General indicators are organized again by resource realm along the vertical axis. Drivers and stressors are aligned along the horizontal axis. An "x" is placed in any box where an indicator intersects with a driver or stressor with which there exists a suspected or known significant relationship as identified by workshop participants. Relationships represent our ecological understanding for one or more ecosystem types. Therefore, not all relationships are applicable to all ecosystem types. General indicators rather than specific indicators are used to limit the model's complexity and to simplify the initial indicator prioritization process for this layer of the model.

Information collected from scoping workshops, inventory study plans, resource management plans, and from discussions with resource managers was used in the initial construction of the matrix. Relationships depicted in the final matrix are the result of expert input from network scoping workshops and may not represent all possible or "apparent" relationships. Rather, the matrix represents relationships identified by workshop participants as being scientifically justifiable and relevant to SFAN monitoring objectives.

The matrix allows for the qualitative comparison of general indicators by showing which indicators are affected by multiple drivers and stressors as well as which stressors affect multiple indicators. In some cases, it may be desirable to choose an indicator with relative specificity to a given stressor. In others, it may be desirable to choose an indicator that can serve as an early warning for multiple stressors. Ideally, both types of indicators are represented in a Vital Signs monitoring program.

Table 2.1a. Significant relationships between general atmospheric indicators and drivers and stressors in the SFAN parks.

RESOURCE REALM	**GENERAL INDICATORS**	**DRIVERS**									**STRESSORS**													
		Solar/Lunar Cycles	Climatic Variability	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
ATMOSPHERE	AIR QUALITY																							
	Chemistry - contaminants										x	x										x		
	Chemistry - nitrogen/ sulfur deposition				x						x	x										x		
	Chemistry - ozone										x	x										x		
	Chemistry - carbon dioxide, methane										x	x										x		
	Physics - fine particles										x	x										x		
	LIGHT and SOUND																							
	Lightscapes	x														x				x				
	Ultraviolet light (B)																							
	Soundscapes															x				x				
	WEATHER and CLIMATE																							
	Climatic variability		x	x	x	x	x	x			x	x										x		

Table 2.1b. Significant relationships between general biotic (faunal) indicators and drivers and stressors in the SFAN parks.

RESOURCE REALM	GENERAL INDICATORS	DRIVERS									STRESSORS													
		Solar/Lunar Cycles	Climatic Variability	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
BIOSPHERE	FAUNAL DYNAMICS																							
	Species distribution and abundance	x	x		x	x	x		x	x			x	x	x	x	x	x	x	x		x	x	x
	Native species of special interest	x	x							x			x	x	x	x	x	x	x	x		x	x	x
	Species at risk	x	x							x			x	x	x	x	x	x	x	x		x	x	x
	Non-native invasive species/disease		x				x	x	x	x			x		x	x	x	x	x	x		x	x	x
	Patch size and proximity		x				x	x	x	x				x	x	x	x	x	x	x		x	x	
	Community area and distribution		x				x	x	x	x			x	x	x	x	x	x	x	x		x	x	x
	Land use patterns		x	x		x	x								x	x	x	x		x				

Figure 2.1c. Significant relationships between general biotic (vegetation) indicators and drivers and stressors in the SFAN parks.

RESOURCE REALM	GENERAL INDICATORS	DRIVERS									STRESSORS													
		Solar/Lunar Cycles	Climatic Variability	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
BIOSPHERE	VEGETATION AND FLORISTIC DYNAMICS																							
	Species richness and diversity		x				x	x	x	x				x	x	x		x				x	x	x
	Native species of special interest	x	x				x	x	x	x				x	x	x		x				x	x	x
	Species at risk	x	x				x	x	x	x				x	x	x		x				x	x	x
	Non-native invasive species/disease						x	x	x	x				x	x	x		x	x	x		x	x	
	Vegetation composition and structure		x				x	x	x	x				x	x	x		x				x	x	x
	Community assemblages	x	x				x	x	x	x	x			x	x	x		x				x	x	
	Fragmentation and connectedness						x	x	x					x	x	x		x				x		
	Land use patterns													x	x	x	x	x			x		x	
	Phenology	x	x			x	x	x	x	x		x	x	x					x					
	Biological processes	x	x		x	x		x	x	x		x	x	x	x	x	x	x				x	x	x

Table 2.1d. Significant relationships between general hydrospheric indicators and drivers and stressors in the SFAN parks.

		DRIVERS									STRESSORS													
RESOURCE REALM	**GENERAL INDICATORS**	Solar/Lunar Cycles	Climatic Variability	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
HYDROSPHERE	Water chemistry		x		x		x	x		x	x		x	x	x	x		x	x	x				
	Water clarity		x		x		x	x					x	x	x	x	x	x	x	x	x			
	Water contaminants		x		x			x					x	x	x			x	x		x			
	Pathogenic bacteria		x		x		x	x		x	x		x	x	x			x	x		x			
	Surface water dynamics		x	x				x		x	x			x	x	x	x			x				
	Groundwater dynamics		x	x				x						x	x	x	x			x				
	Physical oceanography		x			x				x	x					x				x				
	Flooding		x					x		x	x			x		x	x			x				
	Waves	x	x				x				x					x				x				
	Drought		x					x	x	x	x			x								x		

Table 2.1e. Significant relationships between general lithospheric indicators and drivers and stressors in the SFAN parks.

RESOURCE REALM	GENERAL INDICATORS	DRIVERS									STRESSORS													
		Solar/Lunar Cycles	Climatic Variability	Geologic Processes	Nutrient Cycles	Oceanography	Coastal Processes	Hydrologic Processes	Fire Cycles	Biological Processes	Climate Change	Air Quality Degradation	Water Quality Degradation	Water Quantity Alteration	Human Population Increase	Land Use Change/ Development	Resource Extraction	Soil Alteration	Nutrient Enrichment	Park Development / Operations	Recreational Use	Fire Management	Non-native Species Invasions/ Disease	Native Species Decline/ Extirpation
LITHOSPHERE	Habitat associations/surficial geology		x	x	x		x	x		x						x				x		x		
	Soil biota									x								x						
	Soil chemistry and contaminants				x					x		x						x	x					
	Soil structure and texture				x			x	x	x						x		x		x				
	Erosion and deposition (paleoclimate)		x	x			x		x	x	x							x	x					
	Shoreline shifts		x	x			x			x						x				x				
	Earthquakes			x			x	x								x				x				
	Mass wasting		x	x			x				x					x				x				

2.9 Specific Indicator Example

For each general indicator within a given resource realm, relevant specific indicators exist that may be monitored as part of the SFAN monitoring program. As the program proceeds, it will be necessary to design more detailed conceptual models focusing on specific, high priority indicators (Vital Signs). Detailed models will allow the parks to evaluate and choose the most appropriate parameters to measure. Figure 2.6 provides an example of a conceptual model for a potential specific indicator (prairie falcon) in the SFAN parks.

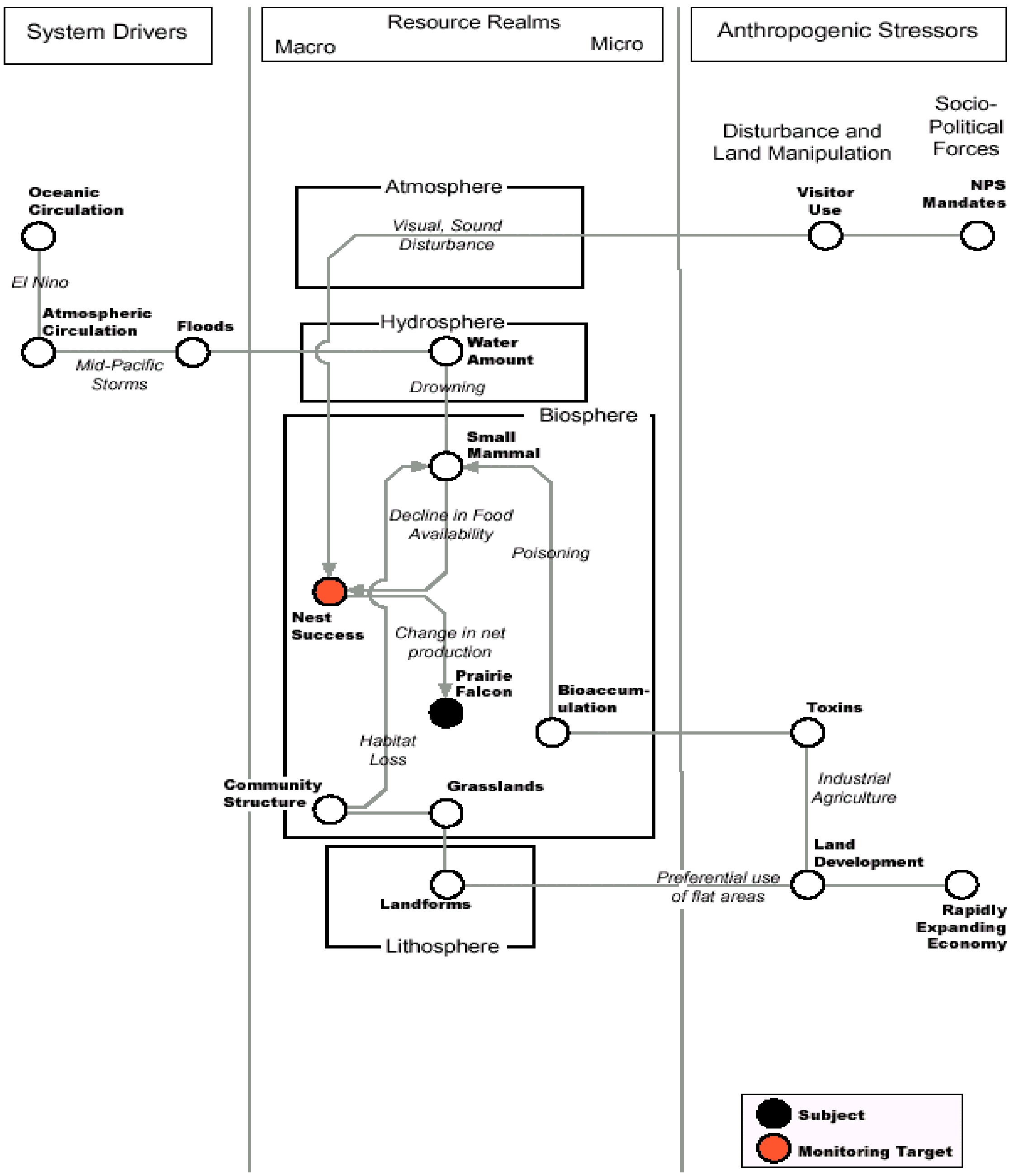


Figure 2.6. Example of a conceptual model for a specific indicator (prairie falcon).

2.10 Implications for Vital Signs Selection

Ecosystems are, by definition, complex systems. Conceptual models assist in isolating ecosystem components, functions, and structures of known or potential importance to the integrity of the system. Each of these “vital” attributes can, therefore, serve as an indicator of ecosystem integrity. Still, the list of possible and credible indicators is long, and there are often multiple metrics that can be measured for each indicator. Spatial sampling design and sampling methods can be complex, however, and may require expensive equipment or analyses. Park networks also have limited fiscal, temporal, and human resources. It is, therefore, necessary to prioritize the list of potential indicators, to determine what indicators are most important for individual parks and for the network. It is also necessary to select from the prioritized list indicators that integrate multiple attributes of ecosystem structure and function and that represent a variety of spatial and temporal scales (Holling 1986). Development of ecological conceptual models is the first step toward selecting appropriate indicators for a Vital Signs monitoring program. Vital Signs selection and prioritization is the next step.

Chapter 3 Vital Signs

3.1 Overview of the Vital Signs Selection Process

The complex task of developing a network monitoring program requires a front-end investment in planning and design to ensure that monitoring will meet the most critical information needs of each park and produce scientifically credible data that are accessible to managers and researchers in a timely manner. The investment in planning and design also ensures that monitoring will build upon existing information and understanding of park ecosystems and make maximum use of partnerships with other agencies and academia. Collectively, the information used to build the monitoring program also functions as ideal criteria by which ecological indicators can be compared and selected for inclusion in the network's Vital Signs monitoring program. Although the networks are not required to follow set methodologies for selecting indicators, it is understood that selection of Vital Signs is an iterative process. Selected Vital Signs are subject to change as fiscal resources and management issues change. Adjustments to the monitoring program also may occur as subsequent monitoring program reviews conducted approximately every five years provide feedback on the efficacy of the selected indicators. Of course, indicators that provide long-term baseline data or are essential to the interpretation of other Vital Signs (e.g., climatological data) have well-established protocols that require continuous and consistent monitoring. Monitoring of these indicators should not shift with changing resources and management issues. The following sections briefly explain the SFAN prioritization process.

3.2 SFAN Vital Signs Selection Process

The SFAN prioritization process has included park scoping activities, network Vital Signs workshop review, indicator refinement by technical expert focus groups, development of an indicator database and indicator ranking criteria, an initial prioritization based on indicator quality and significance, and a Vital Signs prioritization meeting to ensure that indicators represent a range of spatial and temporal scales and resource realms. Indicator information generated from scoping workshops and protocol questionnaires was combined with existing park protocols to create an indicator database for the network. Indicators in this database were ranked using criteria adapted from working models and refined by the Steering Committee to complement the needs of the network. SFAN ranking criteria included management significance, ecological significance, legal mandate consideration, and cost and feasibility. Data comparability and partnership potential were incorporated into these categories. The resulting list of SFAN Vital Signs is detailed in Section 3.3. Table 3.1 highlights some of the important steps in the SFAN process and their action dates.

Table 3.1. Important activities and dates in the SFAN Vital Signs selection process.

Activity	Date(s)
SFAN scoping workshop	March 19-20, 2003
Completion of indicator database and worksheets	June 20, 2003
Open database/website for ranking	June 27, 2003
Close database/website to ranking	July 11, 2003
Completed summary of ranking results	July 24, 2003
Vital Signs prioritization meeting	July 29-30, 2003
Recommendations to Board of Directors for review	August 25, 2003
Submit final draft Phase II report to Regional Coordinator	September 26, 2003

3.2.1 Scoping Workshop Results

The planning process began with a series of park-level scoping workshops in the fall of 2001. In each of these workshops, participants identified significant resources in the parks, identified key processes and stressors affecting the parks, drafted potential monitoring questions, and recommended Vital Signs indicators that could address the monitoring questions. An initial prioritization of Vital Signs indicators and development of a conceptual model also were conducted at the park level.

The March 2003 SFAN Vital Signs Workshop consolidated the park-specific information into a conceptual model, relevant monitoring questions, and potential indicators that could be applied across the network. Consequently, the spatial scale was expanded to include the eco-region and broader scales. Information from the park workshops and the March scoping workshop was used to:

- Revise conceptual model components.
- Develop an indicator database derived from completed protocol questionnaires.
- Identify gaps in our understanding and organization of potential indicators.
- Select methodologies for prioritizing Vital Signs indicators.
- Identify initial sampling designs and monitoring protocols related to the potential indicators discussed in the workshops.

In essence, the workshops provided the foundational materials and direction on which to build the SFAN Vital Signs selection process. A summary of the comments resulting from the workshops can be found in Appendices 1, 2, 3, and 4 or on the SFAN website (http://www.nature.nps.gov/im/units/nw27/report.htm).

3.2.2 Technical Expert Focus Groups

Recommendations made during the March workshop were further refined using technical expert focus groups, i.e. vegetation, wildlife, marine, geology, and water resources. Focus groups consolidated several of the potential indicators so that comparisons could be made among larger groups of indicators (e.g., visibility was combined with the air quality indicator group, and red-legged frogs were combined with the amphibian/reptile indicator group). Focus groups also completed a protocol worksheet for each indicator. Indicator worksheets provide in-depth information about indicator justification, indicator metrics, monitoring scale and methodologies, assumptions, constraints, thresholds for monitoring, and management actions if the thresholds are reached or exceeded (see Table 1.3.)

3.2.3 Indicator and Protocol Database

All available information from existing indicator worksheets (Table 1.3) was entered into a network database developed by the Network Data Manager and based on a data structure provided by the National Monitoring Coordinator. Information gaps were identified and addressed while worksheet information was being entered into the indicator database. Along with worksheet information, network parks and ecosystems in which the indicator may be applicable were noted.

The SFAN database was linked to dynamic web pages posted on the network web site with the intent of using the web pages to enter indicator data and to perform the initial ranking process. This linkage allowed many revisions to be immediately incorporated into the web page. The indicator database and linked web pages also served as the foundation for the SFAN ranking instrument (Section 3.2.5).

3.2.4 Ranking Criteria

The four criteria utilized to rank Vital Signs indicators reflect important qualities of an effective Vital Signs monitoring program and were modified from the Cumberland-Piedmont Network ranking criteria, Jackson et al. (2000), Tegler et al. (2001), and Andreasen et al. (2001) (Table 3.2). Sub-criteria describe the decisive factors associated with each primary criterion, and the prioritization scheme defines the rationale behind assigning a given value to each criterion. **Only NPS staff were provided with a password that gave them access to the Legal Mandates criterion.** Each criterion was weighted to reflect its relative contribution to the selection of SFAN Vital Signs.

Table 3.2. Criteria for prioritizing San Francisco Bay Area Network indicators.

Primary Criteria	Sub-criteria*	Prioritization Scheme
Ecological Significance	o There is a strong, defensible linkage between the indicator and the ecological function or critical resource it is intended to represent. o The indicator represents a resource or function of high ecological importance based on the conceptual model of the system and the supporting ecological literature. o Data from the indicator are needed by the parks to fill gaps in current ecological knowledge. o The indicator provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system. o The indicator has a high signal to noise ratio and does not exhibit large, naturally occurring variability.	*Very High*—I **strongly agree** with at least 7 of these statements. *High*—I **strongly agree** with at least 5 of these statements. *Moderate*—I **strongly agree** with at least 4 of these statements. *Low*—I **strongly agree** with at least 1 of these statements. *Very Low*--This is an important indicator to monitor, but I do not **strongly agree** with any of these statements. *No opinion*--I do not know enough about this criterion for this indicator to

Primary Criteria	Sub-criteria*	Prioritization Scheme
	o The indicator is sufficiently sensitive; small changes in the indicator can be used to detect a significant change in the target resource or function. o Reference conditions exist within the region, and/or threshold values are specified in the available literature that can be used to measure deviance from a desired condition. o The indicator complements indicators at other scales and levels of biological organization.	rank it.
Management Significance	o There is an obvious, direct application of the data to a key management decision, or for evaluating the effectiveness of past management decisions. o The indicator will produce results that are clearly understood and accepted by park managers, other policy makers, research scientists, and the general public, all of whom should be able to recognize the implications of the indicator's results for protecting and managing the park's natural resources. o Data are badly needed to give managers a better understanding of park resources so that they can make informed decisions. o Monitoring results are likely to provide early warning of resource impairment, and will save park resources and money if a problem is discovered early. o In addition to addressing a specific management decision, data provide information that strongly support other management decisions. o Data are of high interest to the public. o There is an obvious, direct application of the data to performance (GPRA) goals.	<u>Very high</u>—I **strongly agree** with at least 6 of these statements. <u>High</u>—I **strongly agree** with at least 5 of these statements. <u>Moderate</u>—I **strongly agree** with at least 3 of these statements. <u>Low</u>—I **strongly agree** with at least 1 of these statements. <u>Very Low</u>**—** Some of the statements above apply to some degree, but I do not **strongly agree** with any of these statements. <u>No opinion</u>**—**I do not know enough about this criterion for this indicator to rank it.
Legal Mandate	This criterion is part of 'Management Significance' but is purposely duplicated here to emphasize those indicators and resources that are required to be monitored by some legal or policy mandate. The intent is to give additional priority to an indicator if a park is directed to monitor specific resources because of some binding legal or Congressional mandate, such as specific legislation and executive orders, or park enabling legislation. The binding document may be with parties at the local, state, regional, or federal level.	<u>Very High</u>—The park is **required** to monitor this specific resource/ indicator by some specific, binding, legal mandate (e.g., Endangered Species Act for an endangered species, Clean Air Act for Class 1 airsheds), or park enabling legislation. <u>High</u>—The resource/indicator is specifically covered by an Executive Order (e.g., invasive plants, wetlands) or a specific Memorandum of Understanding signed by the NPS (e.g., bird monitoring), as well as by the Organic Act, other general legislative or Congressional mandates, and NPS Management Policies.

Primary Criteria	Sub-criteria*	Prioritization Scheme
		Moderate— There is a GPRA goal specifically mentioned for the resource/indicator being monitored, or the need to monitor the resource is generally indicated by some type of federal or state law as well as by the Organic Act and other general legislative mandates and NPS Management Policies, but there is no specific legal mandate for this particular resource. _Low_— The resource/indicator is listed as a sensitive resource or resource of concern by credible state, regional, or local conservation agencies or organizations, but it is not specifically identified in any legally-binding federal or state legislation. The resource/indicator is also covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies. _Very Low_— The resource/indicator is covered by the Organic Act and other general legislative or Congressional mandates such as the Omnibus Park Management Act and GPRA, and by NPS Management Policies, but there is no specific legal mandate for this particular resource. _No opinion_—I do not know enough about this criterion for this indicator to rank it.
Cost and Feasibility	o Sampling and analysis techniques are cost-effective. Cost-effective techniques may range from relatively simple methods applied frequently or more complex methods applied infrequently (e.g., data collection every five years results in low annual cost). o The indicator has measureable results that are repeatable with different, qualified personnel. o Well-documented, scientifically sound monitoring protocols already exist for the indicator. o Implementation of monitoring protocols is feasible given the constraints of site	_Very High_**—**I **strongly agree** with all 6 of these statements. _High_**—**I **strongly agree** with at least 4 of these statements. _Moderate_**—**I **strongly agree** with at least 3 of these statements. _Low_**—**I **strongly agree** with at least 1 of these statements. _Very Low_**—**This is an important indicator to monitor, but I do not **strongly agree** with any of these

Primary Criteria	Sub-criteria*	Prioritization Scheme
	accessibility, sample size, equipment maintenance, etc. o Data will be comparable with data from other monitoring studies being conducted elsewhere in the region by other agencies, universities, or private organizations. o The opportunity for cost-sharing partnerships with other agencies, universities, or private organizations in the region exists.	statements. *No opinion*—I do not know enough about this criterion for this indicator to rank it.

3.2.5 Initial Prioritization Process and Results

The initial prioritization process was conducted using a web-based ranking methodology. The SFAN database and associated web pages functioned as the source of indicator ranking information and as the receptacle for ranking scores and participant comments. The dynamic nature of the database-web page linkage has not only provided the SFAN with a tool for ranking indicators, but it also has given the network the opportunity to export a standard yet flexible tool to other networks that can be adapted to their ranking needs.

Participants from previous workshops, additional subject experts, regional NPS staff, and other selected agency officials were sent a background statement, instructions, and descriptions of ranking criteria via email. All invited participants (156 people) were given a password, giving them access to the ranking website (www.nature.nps.gov/im/units/nw27/database/loginname.cfm) which also contained links to the background and instructional materials. Login names and passwords were used to provide sufficient security during the ranking process. Upon reviewing the instructions and ranking criteria, participants were asked to rank each indicator from very low to very high with respect to each criterion. Participants also had the option of choosing "no opinion" for each criterion if they had insufficient knowledge about the criterion or the indicator to evaluate it. Participants could view the existing data for each indicator, print any or all of the information, rank indicators in accordance with the SFAN criteria, review their scores, and change them as often as the participants wished during the two week window that the database was open.

Additionally, participants were given two locations in which to provide feedback. The comment box under the ranking scores could have been used to justify ranking scores. A comment box at the bottom of the indicator information was intended for information on citations or methods that were not included in the worksheet. Comments were taken into consideration as indicator ranking results were analyzed and will be considered during protocol development.

Of the 156 people invited to rank the proposed SFAN Vital Signs, 55 people participated. Thirty-five (35) of the 55 participants were NPS employees. Weighted scores for the indicators were calculated using three methodologies (i.e., weighted mean scores for each individual for each indicator, weighted mean scores for each criterion for each indicator, and mean weighted scores per individual without accounting for missing values). The resulting rank order of indicators did not differ appreciably among methodologies suggesting that the results were relatively robust. In particular, the positions of the ten highest ranked indicators and three lowest ranked indicators changed very little. Most shifts in rank position from one calculation type to another occurred between adjacently ranked indicators and were the result of slight differences in the second, third, or even fourth decimal place (accuracy beyond the limits of the data but useful for display purposes).

The mean of weighted scores for each individual was calculated for each indicator and analyzed using descriptive statistics (e.g., mean, mode, range, standard deviation). Analyses were performed on the complete data set as well as on subsets of the data. Indicator rankings were sorted and compared based on management significance (only), ecological significance (only), NPS or non-NPS status, the participants' areas of expertise, indicator categories, and spatial scale. Although comparisons were also made with non-weighted mean scores, no comparisons were made with scores unadjusted for missing values since missing values could skew the data appreciably. Descriptive statistics were displayed for all data permutations.

Detailed descriptions of the data calculations and the resulting data comparisons are presented in the Vital Signs Prioritization Meeting Summary (Appendix 10). The initial rankings resulting from the web-based prioritization process are noted in Table 3.3.

3.2.6 Vital Signs Prioritization Meeting

The Vital Signs Prioritization Meeting held at the Presidio's Golden Gate Club, July 29-30, 2003, was designed to review the process used by the network to identify and prioritize Vital Signs indicators, review the results of the web-based ranking, compare the rank order of indicators using different methods of calculating indicator scores and different methods of categorizing the indicators, identify monitoring gaps in the prioritized list, adjust the order of the indicators as necessary, and justify any changes made to the prioritized list.

The first day's discussion included members of the Steering Committee and Board of Directors, and NPS staff with expertise pertinent to the discussion of potential Vital Signs. The day's discussion focused primarily on the scientific and ecological context of the Vital Signs indicators and encompassed three components:

- Explanation of the ranking process and the calculation of the prioritized list based on weighted mean scores,
- Comparison of the mean weighted scores to alternative score calculations and other data sorts, and
- Alterations to the prioritized list based on noticeable trends in the data or information gaps.

Discussion on the second day was designed to address in more detail management issues, monitoring scale, potential partnerships, the status of existing and potential indicator protocols, and other factors associated with the realities of Vital Signs planning and implementation. The second day's discussion included members of the Steering Committee and Board of Directors only.

Following the July 2003 Vital Signs Prioritization Meeting, the Network Inventory and Monitoring Coordinator summarized the meeting's discussions and forwarded the Steering Committee's recommendations to the Board of Directors for review and comment. The Steering Committee recommended that the Board of Directors approve the list of prioritized Vital Signs that resulted from the meeting. The Board reviewed the Steering Committee's recommendation and commented on the prioritized list of indicators. Comments were incorporated into the final list of Vital Signs indicators (Table 3.3).

Results from the SFAN Vital Signs prioritization process were summarized in the July 2003 Vital Signs Prioritization Meeting Summary (Appendix 10).

3.3 Selected Vital Signs

3.3.1 Changes to the Preliminary List of Vital Signs

Alterations made to the initial weighted list of indicators were based on the need to cover a range of ecological scales, a variety of spatial scales, various monitoring objectives, and different indicator types. Discussion focused on indicators that differed among the various data sorts examined, although several other proposed changes were discussed over the course of the two-day Vital Signs Prioritization Meeting (Table 7 in Appendix 10). While a variety of changes were proposed, the most significant changes and their associated justifications are listed below. Those indicators that were promoted in rank are highlighted in boldface type. Any changes made in the order of the indicators, of course, affected the rank of all other indicators. Several name changes and other alterations to the list of mean weighted indicators were proposed. Comments elicited from ranking participants during the ranking process were consulted throughout the prioritization discussion and influenced several decisions. The resulting changes are reflected below and in the recommended list of prioritized vital signs submitted to the Board of Directors.

- **Climatic Variability –** This indicator was moved from position #24 to #1 because the data from this indicator are essential to and support most other indicators, it is network-wide, and it ranked high on the ecological significance criterion list. It was believed that this indicator may have received low scores because another agency is doing most of the monitoring (which should not have affected the significance of the indicator). It also scored in the middle because it does not have high management significance scores.
- **Air Quality –** This indicator was moved from #26 to #4 because of legal mandates (PORE and PINN both are Class I airsheds.), because of ecological importance (Air quality affects water and terrestrial resources.), and because of significant contributions from partners. Again, it was proposed that some scorers did not understand that whether it is being monitored currently or not should not influence its monitoring significance. It is important enough that the network would try to do the monitoring if it were not already being done. It was high on the non-weighted, wildlife and hydrologist lists.
- **Shoreline Shift** (now Coastal Dynamics)– This indicator was moved from #43 to #19 because it is a significant management issue, resources may be lost because of it, baseline information exists, and the Geologic Division will cover most costs. It links to catastrophic events, climate change, and soil erosion/deposition.
- **Physical Oceanography –** This indicator was moved from #41 to #21. It is the physical driver for oceans. NOAA currently collects the data. It is monitored offshore, whereas Marine Water Quality is monitored nearshore. It is high on the ecological significance list.
- **Erosion and Deposition –** This indicator was moved upwards from #42 to #20 because it is the top priority for JOMU and is an issue in all network parks. It encompasses similar issues as Water Quality and Stream Channel/Watershed indicators.

- **Natural Soundscapes** – This indicator was moved from #61 to #29 in response to new legislative mandates for monitoring soundscapes. GOGA will need to monitor sounds in coming years. The FAA will fund some of the monitoring.
- Tule Elk – This indicator remained relatively unchanged (moved from #29 to #27). It is a significant management issue at PORE, is an ecological driver for the ecosystem (grazing), and involved legal issues.
- Oak Woodlands Regeneration (now Oak Woodlands)– This indicator also remained relatively unchanged (moved from #37 to #38). It encompasses both rare and invasive species. It ranked higher than the other three community-based plant indicators. It is not monitored every year. Oaks occur in all parks. Regeneration is sporadic, so the regeneration monitoring was removed from the protocol for this indicator.
- Sudden Oak Death – This indicator changed from #33 to #39. Because it is a relatively new stressor, our understanding of it is limited currently. JOMU will implement monitoring of this indicator while they monitor oak woodlands.
- Rocky Intertidal Community – This indicator was moved from #36 to #32. It is monitored throughout the West Coast, and PORE and GOGA are currently setting up a system to share their data with an existing California/Oregon Coast monitoring group that includes Cabrillo National Monument and Channel Islands National Park (S. Allen pers. comm.) Monitoring has led to NRDA damage assessments. A good baseline exists for post-catastrophic events.
- Groundwater Dynamics – This indicator moved from #38 to #42. It is expensive and issue-specific rather than a form of general monitoring. There is opportunity for funding elsewhere.
- Catastrophic Event Documentation – This indicator was left relatively unchanged (moving from #39 to #44) because it only captures sporadic events. Protocols are needed describing the parameters to measure and standard methodologies to collect data when an event occurs are also needed. This includes data storage and management. This indicator documents how the events affect the ecosystem. Weather and water flow are pre-event; this is post-event. Monitoring data leads to adaptive management. The hydrologist group ranked it in their top ten.
- Corvids – This indicator was left unchanged (moving from #44 to #46) because of uncertainty surrounding monitoring methodology. But, it stays well situated for partnering.
- Shorebirds, Seabirds and Waterbirds were to remain in relative order to each other in the upper medium group because birds act as good indicators, and each one represents a different ecosystem.
- Aquatic Invertebrates were demoted from #31 to #61 because *California Freshwater Shrimp were removed and added to the Salmonid/Fish Assemblage* indicator (which most likely boosted the ranking of Aquatic Invertebrates). It would require a significant effort to develop a baseline for this indicator.

Participants also were given an opportunity to group, rename and identify indicators that were missed earlier in the process. The following changes were made in this regard:

- Plant Community Change at Multiple Scales was divided into two indicators – 1) Landscape and Land Use Change (remote sensing) which was placed at #12, and 2) Plant

Community Change (field crew mapping and measurement) which was placed at #11. There were two different scales, methodologies, and potential funding sources involved. Though divided, these indicators remained relatively unchanged in their ranking.

- Wetlands were added as an indicator. Wetlands include not only plant communities but the hydrologic regime and the physical aspects of the land. Wetlands include both freshwater and marine wetland ecosystems. Wetlands are related to riparian habitat and to freshwater dynamics, so wetlands were placed on the list in that grouping.
- Non-native fish were added to non-native animals.
- Marine fish were added to estuarine fish. The name was changed to Marine and Estuarine Fish.
- Phytoplankton were included with Marine Water Quality.

In addition, the Board of Directors made two changes to the proposed list of prioritized indicators at their August 22, 2003 meeting:

- The Board of Directors combined Feral Pigs/Habitat Damage with Non Native animals. Justification: Feral pigs are a non-native animal, so working groups covering this indicator should consider monitoring of feral pigs along with the other non-native animals that are being monitored.

- Marine & Estuarine Fish (#32) should be moved up to the #25-32 range. Justification: Marine resource information will be critical over the next few years as marine reserves are established. Marine oceanography (#21) will be conducted by other agencies. Knowledge about fish populations is essential. Commercial fisheries are declining and plans are being developed to change the management direction. It was recommended that inventories be completed and development of monitoring protocols commence as soon as practical.

The Steering Committee revised the list based on the Board's comments. The Marine & Estuarine Fish indicator was moved from #32 to #28 on the list to reflect the Board's comments.

3.3.2 Potential Partnerships and Protocol Status

It is incumbent upon the network to establish partnerships and to find additional grants to implement Vital Signs monitoring since NPS I&M funding will not cover all monitoring needs. Partnerships will assist the SFAN in implementing more Vital Signs monitoring projects than would be possible without assistance. Consequently, identification of current and potential partnerships was considered throughout the prioritization process. Some partners have already been identified in the indicator worksheets developed by the technical focus groups. The Steering Committee will continue identifying potential partnerships for each indicator, especially those that are high on the list.

Peer-reviewed protocols also will be needed before monitoring is implemented. The network, therefore, has identified the current status of monitoring protocols for each indicator (Table 3.3).

3.3.3 Vital Signs Indicators

Comments from the Vital Signs Prioritization Meeting and the SFAN Board of Directors were incorporated into the network's final list of prioritized Vital Signs (Table 3.3). The prioritized list is presented in its rank order with reference to the indicators' initial ranks and pertinent changes. Reference also is made to the status of protocols for each indicator.

The network plans to implement the highest ranked indicators first. It is necessary to emphasize that many indicators, especially those indicators in the middle of the range, had virtually identical mean weighted scores. As a result, there was very little distinction between many adjacently ranked indicators. Additionally, the selection of Vital Signs is an iterative process. Selected Vital Signs are subject to change as fiscal resources and management issues change. Adjustments to the monitoring program also may occur as subsequent monitoring program reviews conducted approximately every five years provide feedback on the efficacy of the selected indicators. Therefore, indicators may be chosen for monitoring out of rank order if partnerships present themselves, management issues change, ecological information is updated, or linkages between high-ranked and low-ranked indicators allow for efficient and effective monitoring. Some modifications to this list also may occur throughout this process in response to reviewer comments. Modifications to well-establised, long-term baseline indicators (e.g., climatological data, hydrography) will be limited.

The most recent Vital Signs indicator information compiled from protocol worksheets is available on the SFAN database web site http://www.nature.nps.gov/im/units/nw27/database/indicators.cfm.

Table 3.3. Final list of prioritized Vital Signs for the San Francisco Bay Area Network. "Previous Rank" refers to the indicator rank that resulted from the initial prioritization process. Boldface indicators represent major adjustments. The current protocol status also is listed for each indicator.

New Rank	Previous Rank	Indicator Name	Protocol Status*
1	24	**Climatic Variability**	2
2	1	Invasive Plant Species (terrestrial & aquatic)	1
3	2	Freshwater Quality	3
4	26	**Air Quality**	4
5	3	Stream T&E Species & Fish Assemblages (Salmonids)	3
6	4	Rare, Threatened, and Endangered (T&E) Plant Species	2
7	5	Northern Spotted Owl	3
8	6	T&E Amphibians and Reptiles	3
9	7	Western Snowy Plover	3
10	8	Pinnipeds	3
11	9	Plant Community Change (at two different scales)	2
12	9	Landscape & Land Use Change (evolved from Plant Community Change at Multiple Scales)	3
13	10	Threatened and Endangered (T & E) Butterflies	2
14	12	Freshwater Dynamics (Stream Hydrology)	2
15	**New**	**Wetlands**	2

New Rank	Previous Rank	Indicator Name	Protocol Status*
16	13	Riparian Habitat	2
17	14	Birds-Landbirds	3
18	15	Raptors and Condors	3
19	43	**Coastal Dynamics (formerly Shoreline Shift)**	3
20	42	**Erosion and Deposition**	2
21	41	**Physical Oceanography**	4
22	16	Dune Vascular Plant Assemblages	1
23	11	Non-Native Animals (includes terrestrial & aquatic)	2
24	19	Birds-Shorebirds	3
25	20	Birds-Seabirds	3
26	21	Birds-Waterbirds	3
27	29	Tule Elk	3
28	32	Marine and Estuarine Fish **(changed name)**	2
29	61	**Natural Soundscapes**	2
30	22	Medium to Large Carnivores	2
31	23	Stream Channel and Watershed Characterization	3
32	36	**Rocky Intertidal Community**	4
33	25	Marine Water Quality	2
34	27	Townsend’s Big-Eared Bats	3
35	46	Bank Swallow	2
36	28	Small Mammals and Herpetofauna (inc. Coast Horned Lizard)	3
37	31	Grassland Plant Communities	2
38	37	Oak Woodlands **(changed name)**	2
39	33	Sudden Oak Death	3
40	34	Resilience Monitoring – Fire	1
41	35	Bat Guild	2
42	38	Groundwater Dynamics	2
43	39	Catastrophic Event Documentation	1
44	48	Subtidal Monitoring	2
45	40	Lichens	3
46	44	Corvids	2
47	45	Cave Communities	1
48	47	Terrestrial Invertebrate Community (non-T&E)	1
49	49	Resilience Monitoring – Flood	1
50	50	Pelagic Wildlife	3
51	51	Wildlife Diseases	2
52	52	Landform Type	3
53	53	Natural Lightscape	3
54	54	Ozone (O_3) Sensitive Vegetation	2
55	55	Soil Biota	3
56	56	Black-tailed Deer	3
57	57	Mass Wasting (Landslide)	2
58	58	Plant Species at the Edge of their Range	1

New Rank	Previous Rank	Indicator Name	Protocol Status*
59	59	Sandy Intertidal Community	2
60	60	Cetaceans	3
61	31	**Aquatic Invertebrates**	3
62	62	Soil Structure, Texture, and Chemistry	3
63	63	Viewshed	3

*1=nothing available; 2=being developed; 3=standard methodologies exist; 4=needs review; 5=reviewed.

3.3.4 Alternate Indicators

The SFAN presented the prioritized Vital Signs indicators as one list in rank order rather than present a list of high priority indicators and a separate list of alternate indicators. This approach emphasizes the importance of each indicator proposed during the selection and prioritization process. One contiguous list also emphasizes the partnership and monitoring potential that exists among many Vital Signs. This potential would be less apparent if the network's Vital Signs were divided into distinct priority groups, divisions that would be artificially imposed on the prioritized list.

For FY04, the SFAN has identified funding and/or partnerships to provide for the protocol development and implementation of the first 21 Vital Signs (Table 3.3). The remaining Vital Signs will be addressed as resources and/or partnerships present themselves.

3.3.5 Specific Measurable Objectives

Specific measurable objectives are listed in Appendix 11 for the first 21 Vital Signs indicators (Table 3.3) resulting from the prioritization process. More information will become available as indicator protocols are developed. Related information for each proposed indicator is included in the SFAN indicator database (http://www.nature.nps.gov/im/units/nw27/database/indicators.cfm).

3.3.6 Threshold Values

Threshold or target values are listed where available in Appendix 11 for the first 21 Vital Signs indicators (Table 3.3) resulting from the prioritization process. More information will become available as indicator protocols are developed. Values are included where available for the remainder of the SFAN Vital Signs indicators in the network's indicator database (http://www.nature.nps.gov/im/units/nw27/database/indicators.cfm).

3.3.7 Management Responses

Management responses are listed in Appendix 11 for the first 21 Vital Signs indicators (Table 3.3) resulting from the prioritization process. More information will become available as indicator protocols are developed. An initial list of management responses associated with each proposed indicator can be found in Appendix 6 or in the SFAN indicator database (http://www.nature.nps.gov/im/units/nw27/database/indicators.cfm).

3.4 Water Quality Vital Signs

Water quality-related Vital Signs were discussed in Section 1.3.2.2: Water Resources Monitoring Efforts and Questions, and Potential Indicators. The following water resources indicators were included in the SFAN ranked list of Vital Signs Indicators:

#1 Climatic Variability
#3 Freshwater Quality
#14 Freshwater Dynamics (Stream Hydrology)
#15 Wetlands
#16 Riparian Habitat
#20 Erosion and Deposition
#31 Stream Channel and Watershed Characterization
#33 Marine Water Quality
#42 Groundwater Dynamics
#61 Aquatic Invertebrates

The inclusion of these indicators in the ranking list is indicative of the significance of aquatic resources in the network. Several NPS efforts to improve water resources within SFAN are underway; continued and augmented monitoring is needed to ensure that existing linkages among these indicators remain viable.

Because of the presence of threatened and endangered species, Section 303d listed waters, significant coastal waters, unstable geomorphology, and public water use and health issues, network watersheds receive substantial attention from the surrounding communities and government agencies. The San Francisco Bay Regional Water Quality Control Board identified both Lagunitas Creek and Tomales Bay (PORE/GOGA) as impaired by fecal coliform, sediment, and nutrients. San Francisquito Creek is also sediment-impaired; one of its sub-watersheds is located within GOGA boundaries. Erosion is not only a significant issue for these sediment-impaired waters, but it is also <u>the</u> major watershed issue at JOMU.

The State Water Resources Control Board has established four coastal Areas of Special Biological Significance (ASBS) within the legislative boundaries of the SFAN parks. Because of the significance of these areas as high quality habitat and the need to protect human health (i.e., contact and non-contact recreation), marine water quality will remain an important aspect for the network. Monitoring groundwater dynamics will become more important at PINN as water demand (primarily related to viniculture surrounding the park) increases, thereby applying greater stress to surrounding ecosystems.

3.5 Connectivity Between Selected Vital Signs and the SFAN Conceptual Model

Justification for selection of monitoring indicators is ultimately dependent on a linkage between the selected Vital Signs and the network conceptual models. To ensure that the major conceptual model components are represented by the selected Vital Signs, indicators were organized by resource realm, indicator categories, and by dominant ecosystem types depicted in the models (Table 3.4; refer to Chapter 2: Conceptual Models). Not all of the specific indicators considered for monitoring are presented in the table; for complete lists of indicators, see Appendix 4. Indicators also could have been organized at a finer scale; however, they are represented here at a broader scale for ease of review. Linkages with habitat components, physical resources, and other indicators will be presented as part of the individual conceptual models developed for each Vital Signs indicator. (See Figure 2.6 for an example.)

Table 3.4. List of specific indicators linked to conceptual models. Rank number is the priority number from the ranking procedure. Park codes are 1=EUON, 2=FOPO, 3=GOGA, 4=JOMU, 5=MUWO, 6=PINN, and 7=PORE. Letters signify the application of a given indicator to the ecosystem types: M=marine, T=terrestrial, and W=wetland.

RESOURCE REALM	**INDICATOR CATEGORY** **Indicator**	**Specific Indicators**	**Rank**	**Parks**	**Ecosystems**
ATMOSPHERE	AIR QUALITY		4		
	Chemistry - contaminants (persistent organic pollutants (POPs), mercury, lead, zinc, cadmium)			All	MTW
	Chemistry - nitrogen/ sulfur deposition			1,3,4,6,7	TW
	Chemistry – ozone (ozone sensitive vegetation)		54	1,3,4,6,7	T
	Chemistry - carbon dioxide, methane			3,4,5,6,7	MTW
	Physics - fine particles (human health, visibility concerns)			1,2,3,4,6,7	MT
	LIGHT and SOUND				
	Dark night sky/ light pollution		53	3,5,6,7	MT
	Natural sound levels		29	3,4,5,6,7	MTW
	WEATHER and CLIMATE				
	Climatic variability		1	All	MTW
		Microclimate		1,3,7	T
L	SOIL BIOTA and QUALITY				
	Soil chemistry and contaminants		62	3,5,6,7	MTW
		Contaminants Nutrients Hydrophobicity		3,7 3,7 3,6,7	W TW W
	Soil structure and texture		62	3,5,6,7	MTW
		Compaction Depth of top soil Texture Biotic crust		3,6,7 3,7 All 6	T TW TW T
	Erosion and deposition		20	1,3,4,5,6,7	MTW
	Soil biota		55	1,3,4,5,6,7	MTW
	DISTURBANCE EVENTS				
	Coastal dynamics		19	2,3,7	MW
	Earthquakes			2,3,4,5,6,7	MTW
	Mass wasting		57	3,4,5,6,7	MTW
	Catastrophic event		43	All	MTW
	HABITAT PATTERNS				
	Habitat changes—physical (terrestrial, stream substrate change, channel and drainage morphology, seabed change)			All	MTW

		Landform type/ distribution	52	1,3,4,6,7	T
		Stream channel and watershed characterization	31	3,7	W
		Caves	47	6	TW

HYDROSPHERE	WATER QUALITY		3		
	Chemistry--core elements (temperature, specific conductance, pH, DO)			All	MTW
	Clarity (turbidity and siltation)			3,5,6,7	MTW
	Contaminants (nutrients, organic/ inorganic contaminants, metals)			1,3,4,5,6,7,	MTW
	Groundwater quality			1,3,5,6,7	TW
	Pathogenic bacteria			3,6,7	MW
		Coliform bacteria		3,7	MW
	WATER QUANTITY		3		
	Surface water dynamics (flow, discharge, use)		14	All	TW
	Groundwater dynamics (water tables, recharge, draw down, use)		42	3,6,7	TW
	OCEANOGRAPHY				
	Physical parameters (sea level change, current patterns, upwelling intensity)		21	2,3,5,7	MW
		Upwelling intensity		2,3,5,7	MW
		Sea level change		2,3,5,7	MW
		Water temperature		2,3,5,7	MW
		Change in current patterns		2,3,5,7	MW
	Marine water quality		33	2,3,5,7	MW
	DISTURBANCE EVENTS				
	Resilience monitoring--floods		49	2,3,4,6,7	MTW
	Waves			2,3,7	M
	Catastrophic events		43		
B	FAUNAL CHARACTERISTICS				
	Species richness and diversity – selected communities			All	MTW
		Benthic macroinvertebrates		3,7	W
		Aquatic invertebrates	61	3,5,6,7	W
		Terrestrial invertebrates		1,4	T
		Bees		4	T
		Soil invertebrates	55	3,7	T
		Butterfly/ pollinator guild		3,6,7	T
		Amphibians	8	1,3,4,5,6,7	W
		Lizard guild	36	All	T
		Rockfish	28	3,7	M
		Freshwater fish assemblages	5	3,5,6,7	W
		Marine and estuarine fish	28	3,7	MW
		Shellfish		3,7	M
		Shorebird guilds	24	3,7	M
		Seabirds	25	3,7	M
		Waterbird guilds	26	3,7	M
		Raptors	18	1,3,4,6	T
		Landbird guild	17	All	TW
		Owls	18	4	T
		Small mammal guild	36	All	T
		Medium to large carnivore	30	All	TW
		Pinnipeds	10	3,7	MW
		Cetaceans	60	3,7	M
		Bat guild	41	3,4,5,7	T
		Edge of range species	58	All	T

	Pelagic wildlife	50	3,7	M
Native species of special interest (presence, population size, trends)			All	MTW
	Herring	28	3,7	M
	Krill		3,7	M
	Starfish (*Pisaster*)	32	3,7	M
	Blue-grey gnatcatcher	17	6	T
	Botta pocket gopher	36	1,4	T
	California ground squirrel		1,4	T
	California thrasher	17	6	T
	Sage sparrow	17	6,7	T
	Spotted towhee	17	6,7	T
	Wrentit	17	6,7	T
	Corvid birds	46	3,5,7	TW
	Ghost crab (*Emerita*)		3,7	M
	Coyote	30	3,4,7	T
	Mountain lion	30	3,4,7	T
	Bobcat	30	3,4,7	T
	Grey fox	30	3,4,7	T
	Black tail deer	57	3,4,5,7	T
	Badger	30	3,7	T
Faunal species at risk (presence, trends, population size, genetic diversity--			3,5,6,7	TW
See Section 1.3.1.10 for more complete list of species at risk.)	T&E butterflies	13		
	Point Reyes blue butterfly	13	7	T
	Marin elfin butterfly	13	3,7	T
	Mission blue butterfly	13	3	T
	San Bruno elfin butterfly	13	3,7	T
	Bay checkerspot butterfly	13	3,7	T
	Myrtle's silverspot	13	7	T
	California freshwater shrimp	5	3,7	M
	Coho salmon	5	3,5,7	MW
	Chinook salmon	5	3	MW
	Steelhead trout	5	3,5,7	MW
	Pacific sturgeon	28	3,7	M
	Tomales roach	28	3,7	M
	Pacific lamprey	28	3,7	M
	Sacramento perch		7	M
	Unarmored three spine stickleback	28	7	M
	California red-legged frog	3	3,5,6,7	TW
	Foothill red-legged frog	3	3	TW
	Northern red-legged frog	3	3	TW
	California tiger salamander	3	7	W
	Northwestern pond turtle	36	3,7	W
	Southwestern pond turtle	36	3	W
	California horned lizard	36	3	W
	San Francisco garter snake	36	3	T
	Alameda striped racer	36	7	T
	Loggerhead sea turtle		3,7	M
	Green sea turtle		3,7	M
	Leatherback sea turtle		3,7	M
	California brown pelican	25	3,7	M

		Bald eagle	18	3,7	MTW
		American peregrine falcon	18	3,6,7	T
		California condor	18	6	T
		Marbled murrelet	25	3,7	M
		Bank swallow	35	3,7	TW
		Long-billed curlew	24	3,7	MW
		Ashy storm-petrel	25	7	M
		Elegant tern	25	3,7	MW
		Western snowy plover	9	3,7	M
		Northern spotted owl	7	3,5,7	T
		Willow flycatcher	17	3,7	T
		Loggerhead shrike	17	3,7	T
		Bell's sage sparrow	17	3,7	T
		Great egret	25	3,7	MW
		Golden eagle	18	3,7	T
		Northern harrier	18	3,7	T
		Osprey	18	3,7	MTW
		Merlin	18	3,7	T
		Yellow warbler	17	3,7	T
		Brandt's cormorant	26	3,7	MW
		Double crested cormorant	26	3,7	MW
		Black oystercatcher	26	3,7	M
		Western gull	26	3,7	M
		California quail	17	3,7	T
		Band-tailed pigeon	17	3,7	T
		Rufous hummingbird	17	3,7	T
		Allen's hummingbird	17	3,7	T
		Nuttall's woodpecker	17	3,7	T
		Olive-sided flycatcher	17	3,7	T
		Pacific-slope flycatcher	17	3,7	T
		Warbling vireo	17	3,7	T
		Chestnut-backed chickadee	17	3,7	T
		Swainson's thrush	17	3,7	T
		California thrasher	17	3,7	T
		Black-throated gray warbler	17	3,7	T
		Hermit warbler	17	3,7	T
		MacGillivray's warbler	17	3,7	T
		Lark sparrow	17	3,7	T
		Song sparrow	17	3,7	T
		Black-headed grosbeak	17	3,7	T
		Wrentit	17	3,7	T
		Tule elk	27	7	T
		Salt marsh harvest mouse	36	3	MT
		Point Reyes jumping mouse	36	3,7	MT
		Point Reyes mt. beaver	36	7	TW
		SF dusky-footed woodrat	36	3	T
		Townsend's big eared bat	34	3,7	T
		Pallid bat	41	3	T
		Long-eared bat	41	3,7	T
		Fringed myotis	41	3,7	T
		Long-legged bat	41	3,7	T
		Yuma myotis	41	3,7	T
		Greater western mastiff bat	41	3,7	T

	Southern sea otter		3,7	M
	Steller (northern) sea lion	10	3,7	M
	Guadalupe fur seal	10	7	M
	Northern fur seal	10	7	M
	California sea lion	10	3,7	M
	Harbor seal	10	3,7	MW
	Elephant seal	10	7	M
	Blue whale	60	3,7	M
	Humpback whale	60	3,7	M
	California gray whale	60	3,7	M
	Sei whale	60	7	M
	Finback whale	60	7	M
Exotic animal species/ disease (#, area covered, rate of spread)		23	All	MTW
	Zebra mussels		3,7	M
	Green crab		3,7	M
	Domestic/feral cats		1,4	T
	Lyme disease		4	T
	Withering foot syndrome (abalone)		3,7	M
	Chronic Wasting Disease		3,7	T
	West Nile Virus		All	WT
	Asian clams		3,7	M
	European starling		1,4	T
	Feral pigs		6	T
	Brown headed cowbird		3,7	T
	Red fox		3,4,7	T
	Fallow & axis deer		3,7	T
	Wildlife diseases	52	3,4,6,7	MTW
INTERSPECIFIC INTERACTIONS				
Selected species' interactions (herbivory, predation, competition)			1,3,4,5,6,7	MTW
	Deer browse		1,4	T
FLORAL CHARACTERISTICS				
Species richness and diversity – selected communities			All	MTW
	Macroalgae	44	3,7	W
	Phytoplankton		3,7	MW
	Chaparral vascular plants		3,7	T
	Coastal scrub vascular plants		3,7	T
	Lichens	45	1,3,4,6,7	T
	Oaks	38	1,3,4,7	T
	Riparian vascular plants	16	3,6,7	W
	Vascular dune plants	22	3,7	M
	Serpentine grassland plants	37	3,7	T
	Bulb species		6	T
	Native bunchgrasses	37	1,6	T
Native species of special interest (presence, population size, trends)			All	MTW
	Bishop pine		3,7	T
	Grey pine		6	T
	Black Oak	38	1,4	T
Floral species at risk (presence, trends, population size, genetic diversity)		6	2,3,4,5,6,7	TW

--See Section 1.3.1.10 for a more complete list of species at risk..				
Invasive exotic plant species/ disease (#, area covered, rate of spread of selected species)		2	All	MTW
-- See Section 1.3.1.10 for a more complete list of invasive species.	Sudden oak death	39	1,3,4,7	T
Plant community composition and structure - change at multiple scales		11	All	MTW
	Edge of range species	58		
LANDSCAPE PATTERNS				
Community assemblages (area/ distribution)			All	MTW
	Barnacle/mussel community	32	3,7	M
	Oak woodland community	38	1,3,4,7	T
	Algal assemblages	32	3,7	M
	Muir meadow		4	T
	Floodplain terrace		1,4	TW
	Mt. Wanda peak grassland		4	T
	Pastoral cultural scene		4	T
	Grassland	37	1,6	T
	Riparian/woodland edge plant community	16	1,3,4,6,7	TW
	Douglas fir and coast redwood forests		3,5,7	T
	Wetlands	15	3,7	W
	Rock and scree community		6	T
	Chaparral community		6	T
	Coastal dune community	22	3,7	MTW
	Rocky intertidal community	32	3,7	M
	Sandy intertidal community	59		
	Subtidal community	44	3,7	M
Fragmentation and connectivity			All	TW
	Riparian corridors		3,7	W
	Open space		1,3,4,6,7	T
	Migratory corridors		1,4	TW
Landscape and land use change (urban, agriculture, residential, grazing, wetlands)		12	All	MTW
	Grazing acreage		1,4,7	T
	Urban: open space edge		3,7	T
	Wetland distribution		3,7	W
	Surrounding land use		All	MTW
	Change in land use		1,3,4,6,7	T
	Farming acreage		3,7	MTW
	Stream habitat surveys		3,7	W
	Past land use practices		All	MTW
	Marine fishing zones		3,7	WM
ECOSYSTEM PROCESSES				
Succession			3,5,6,7	MTW
Nutrient dynamics			1,3,4,5,6,7	MTW
DISTURBANCE EVENTS				

	Fire			1,3,4,5,6,7	TW
		Fire suppression Fire prescription		1,3,4,5,6,7 1,3,4,5,6,7	TW TW
		Resilience monitoring	40	1,3,4,5,6,7	TW
SOCIAL	VISITOR USE				
	Recreational use (numbers, types)			All	MTW
		Number/ location Sanitation Social trails Climbing Driving		All 6 3,6,7 6 6	MTW MTW T T T
	Viewshed		63	All	MT

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Glossary

Adaptive Management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form–"active" adaptive management–employs management programs that are designed to experimentally compare selected policies or practices, by evaluating alternative hypotheses about the system being managed.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). See Indicator.

Biological integrity has been defined as the capacity to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region (Karr and Dudley 1981).

Ecological effects are the physical, chemical and biological responses to drivers and stressors.

Ecological integration involves considering the ecological linkages among system drivers and the components, structures, and functions of ecosystems when selecting monitoring indicators.

Ecological (ecosystem) integrity is a concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations and communities and the occurrence of ecological processes at appropriate rates and scales as well as the environmental conditions that support these taxa and processes. Indicators of ecosystem integrity are aimed at early-warning detection of presently unforeseeable detriments to the sustainability or resilience of ecosystems.

Ecosystem is defined as, "a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Likens 1992). Three main ecosystems were identified for the network of parks; terrestrial, wetland and marine.

Ecosystem drivers are major <u>external</u> driving forces such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods) that have large scale influences on natural systems. Trends in ecosystem drivers will suggest what kind of changes to expect and may provide an early warning of presently unforeseen changes to the ecosystem. **Natural ecosystem processes** include both external and internal forces and processes (e.g., herbivory, respiration, productivity).

Ecosystem management is the process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem and is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal of sustainability of ecosystem structure and function, recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. Coordination of land-use decisions is implied by the whole-system focus of ecosystem management.

Focal resources are park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Forms are sub-categories within each ecosystem. Marine forms include ocean, sandy beach, rocky intertidal, bay/estuary; aquatic/wetland forms include running water, standing water, and ground water and apply to both freshwater and saltwater wetlands; and terrestrial forms include grassland, shrubland, woodland, and distinct landforms (e.g., serpentine).

Indicators are a subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2002). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system, known or hypothesized effects of stressors, or elements that have important human values.

Measures are the specific feature(s) used to quantify an indicator, as specified in a sampling protocol.

Programmatic integration involves the coordination and communication of monitoring activities within and among parks, among divisions of the NPS Natural Resource Program Center, and among the NPS and other agencies, to promote broad participation in monitoring and use of the resulting data. At the park or network level, for example, the involvement of a park's law enforcement, maintenance, and interpretative staff in routine monitoring activities and reporting results in a well-informed park staff, wider support for monitoring, improved potential for informing the public, and greater acceptance of monitoring results in the decision-making process.

Resource realms include four major categories— biosphere, hydrosphere, atmosphere, and lithosphere. These realms were used to conceptualize broad categories of interrelated ecosystem processes and components.

Socio-political forces are the laws, mandates, economic pressures and environmental perceptions influencing political decisions that bear upon anthropogenic stressors, and thereby, have a cascading effect on ecosystem function. These can include environmental laws (ESA, CWA, etc.), budgets, and changing social values.

Spatial integration involves establishing linkages of measurements made at different spatial scales within a park or network of parks, or between individual park programs and broader regional programs (i.e., NPS or other national and regional programs).

Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. **Anthropogenic stressors** are those perturbations to a system that directly result from human activity. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Temporal integration involves establishing linkages between measurements made at various temporal scales. It requires nesting the more frequent and, often, more intensive sampling within the context of less frequent sampling.

Umbrella species are typically large-bodied, wide-ranging species that require large patches of habitat and corridors connecting these patches to maintain viable populations. By protecting areas large enough to maintain these species, sufficient habitat can also be maintained which ensures the viability of most other species in that area.

Vital Signs, as used by the National Park Service, are the subset of indicators chosen a by park or park network as part of the Vital Signs Monitoring Program. They are defined as any measurable feature of the environment that provides insights into changes in the state of the ecosystem. Vital Signs are intended to track changes in a subset of park resources and processes that are determined to be the most significant indicators of ecological condition of those specific resources that are of the greatest concern to each park. This subset of resources and processes is part of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on these resources. Vital Signs may occur at any level of organization including landscape, community, population, or genetic levels, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).